

Chapter

Dragon's Blood Tree (*Dracaena cinnabari*): A Cenozoic Relict

Sanjay Saraf

Abstract

The Dragon's blood tree (*Dracaena cinnabari*) woodland is one of the oldest surviving endangered forest communities on Earth. This unique endemic species of Dragon's blood tree is famous since antiquity for its bright red resin "Dragon's blood" and umbrella-shaped canopy. They are almost extinct everywhere except present as small habitats in Socotra Archipelago (Yemen), a UNESCO World Heritage Site. In the last two decades, there has been a significant decline in Dragon's blood tree population in the archipelago, posing a threat to its existence. We attempt to review the status of Dragon's blood tree population in Socotra Archipelago, factors affecting its survival, and the status of conservation efforts propose recommendations to preserve this flagship species.

Keywords: *Dracaena cinnabari*, Dragon's blood tree, Socotra Island, biodiversity, vulnerable, endemism

1. Introduction

The Socotra Archipelago is one of the most significant and well-preserved island ecosystems in the world and holds global significance for the exceptional level of biodiversity and endemism in its ecosystem. Socotra Island is a masterpiece of evolution, containing a unique assemblage of species and habitats, and is ranked as the world's tenth richest island for endemic plant species per square kilometer, with 37% endemic species, which makes the ratio comparable with that of the Galapagos and higher than those found in Mauritius, Rodrigues, or the Canary Islands [1]. The high level of endemism seen in the archipelago is also in accordance with its estimated geological age and ecosystem. Socotra island is home to over 350 species of endemic plant species and is considered as a gem of biodiversity in the Arabian Sea [2–4]. Dragon's blood tree significantly contributes to this endemic biodiversity and is the dominant iconic species of the island (**Figure 1**), (Video available at <https://bit.ly/3Dx92h6>), [5].

1.1 Dragon's blood tree geographical location

The Socotra Archipelago is part of the Republic of Yemen and is geographically located in the north-western corner of the western Indian Ocean, at the junction



Figure 1.
*Dragon's blood tree (*D. cinnabari*), "flagship species of Socotra" (photograph by the author; Socotra 2018).*



Figure 2.
Overview map of the Socotra archipelago, a remarkable biodiversity spot, showing its isolated geographic location in the Indian Ocean.

between the Gulf of Aden and the Arabian Sea, about 380 km off the coastline of Yemen and 250 km east of Cape Guardafui (Somalia), the tip of the Horn of Africa (**Figure 2**).

The Socotra Archipelago is 250 km long and comprises a group of four islands and other small islets. Socotra forms the largest island of the eponymous archipelago of four islands (about 95% of its landmass), followed by the three satellite islands,



Figure 3.
Socotra archipelago “Galapagos of the Indian Ocean” long geologic isolation is the key to preservation of Socotra’s endemic ecosystem.

which are collectively known as “the brothers,” Samha, Darsa, and Abd Al Kuri, and other small rocky islets Jazirat, Sabuniya, and Ka’l Fir’awn, which are uninhabitable (**Figure 3**) but exhibits high level of endemism, rendering the archipelago as a whole even more significant.

The official name of the island is Socotra (often spelled as sokotra, Soqotra or Suqotra), which emanated from the Arabic word *Souq-Al-Qatr*; ‘Souq’ meaning “the market” and ‘Cotra’ referring to “dragon’s blood”—a reference to the bright red resin produced by Dragon’s blood tree species. The main language is Socotri, which is one of the Semitic languages, and Arabic is the official and commonly spoken language.

1.2 Dragon’s blood tree taxonomic hierarchy

Dracaena (Greek: δράκαινα, drakaina “female dragon”) genus comprises between 60 and 100 *Dracaena* species, *D. cinnabari* being one of the only six species that grow as a tree and is considered a terrestrial monocotyledon representative of the Tertiary flora (**Table 1**, **Figure 4**).

1.3 Dragon’s blood tree ecosystem evolution and morphological characteristics

Dragon’s blood trees species belong to one of the oldest ecosystems in the world. Dragon’s blood tree species are spectacular relicts of the Mio-Pliocene Laurasian subtropical forest in Socotra (Yemen) [7]. In this epoch, Dragon’s tree vegetation extended in a continuous vegetation belt between Northern Africa and Southern Europe, but afterward, it was disrupted due to climatic changes, causing the desertification of North Africa [8]. Today, *D. cinnabari* is vulnerable and almost extinct everywhere due to the Pliocene climate changes and extensive desertification of North Africa and Southern Europe [4, 7, 9].

D. cinnabari is a monocotyledonous tree with a distinctive umbrella-shaped canopy due to a “dracoid” ramification of branches (**Figure 5**), [10]. *Dracaena* species are exceptional among monocotyledonous plants because of their capacity for



Figure 4.
Dragon's blood tree (D. cinnabari Baif.f): 'Singular dominant endemic community of Socotra.' This unique tree symbolizes a close bond between nature and the indigenous inhabitants of the island. (photograph by the author, Socotra 2018).

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Lilianae
Order	Asparagales
Family	Asparagaceae
Subfamily	Nolinoideae
Genus	Dracaena L.
Species	<i>D. cinnabari</i> Baif.f Dragon's Blood Tree

Table 1.
Taxonomic serial No.: 505865 [6].

secondary thickening of stems and roots [11]. The *D. cinnabari* is a dominant endemic evergreen tree and can live for more than 500 years, often reaching a height of 35 to 39 feet and is vulnerable to extinction.

1.4 Dragon's blood tree present distribution status

The Socotra Island is approximately 110 km long and about 40 km wide, with a total surface area of 3625 km². The island can be geographically divided into three main zones, namely Haggier (Hagghier, Hajhir) mountains, limestone plateau with



Figure 5.
Dragon's blood trees (D. cinnabari): The "dracoid" ramification of branches is an adaptation to its harsh environment, which helps in capturing the moisture in the arid environment. ("physiologic plasticity") (photograph by the author, Socotra 2018).

many cave systems, and the alluvial coastal plains. The Haggier mountains form the backbone of the island and are situated in the northwest part of the island. Its highest elevation is at Jabal Dryet (1526 m) in the central Haggier Massif. In general, the summit of the limestone plateau is covered with sparse shrubland or low woody-herb communities. The coastal plains are sub desertic with open shrubland or in some areas devoid of vegetation.

In general, Dragon's blood trees occur typically in small dense groups and are found on higher slopes of the limestone mountains, particularly in the central and eastern parts of the island (**Figures 6 and 7**).

Dragon's blood tree woodlands are preponderant in the large central plateau of Diksam (Dixam), the central granite massive of Haggier, and the eastern area of Hamadero, Sirahon, and Kilisan [12]. Several smaller and disrupted *Dracaena* populations exist on Kilim, Sirahan, Shibhon, and other less accessible localities. A dense Dragon's blood tree forest is present in the limestone plateau, known as Roqeb di Firmihin. According to a recent study [5], this small plateau occupies only 2% of the total suitable area currently occupied by the endemic Dragon's blood trees of Socotra, yet it hosts more than 40% of the living population of all *D. cinnabari* trees, making it an attractive hotspot for researchers.

Dragon's blood tree density is not homogenous and has a fragmented distribution, with predominant presence in the central and eastern parts of the island as mentioned earlier. The area of distribution ranges from an altitude of 150 to 1600 m above sea level, and it dominates above 600 meters above sea level (m.a.s.l) [5]. Dragon's blood trees are not seen in the seaside plains, lowlands (below 180 m.a.s.l), and the western part of the island [12].

In the past, Dragon's blood tree habitats were present over larger areas of the island. However, currently, habitats of Dragon's blood tree are dwindling, and several authors have described the *D. cinnabari* habitat decline on Socotra Island [1, 7, 10, 11, 13, 14].



Figure 6.

*Socotra: General view of habitat. *D. cinnabari* is the unique identity of Socotra Island and now occupies only 5% of its habitat. (photograph by the author, Socotra 2018).*



Figure 7.

Dragon's blood tree on a higher plateau. The endangered Dragon's blood trees are strongly tied to the culture of the Socotran people. (photograph by the author, Socotra 2018).

Till the 19th century, the geology of the Socotra Archipelago received little attention, with limited mention of the Dragon's blood tree population in the Socotra archipelago. Most articles published in the late 19th and early 20th centuries were descriptions of endemic species collected by visitors and researchers to the islands. The first description of Dragon's blood tree in the literature was mentioned during the survey of Socotra

led by Lieutenant J.R. Wellsted of the East India Company in 1835 [15]. He named the tree as *Pterocarpus draco* (Greek: πτερον, pteron, “wing” + Latin” carpus from Greek: καρπός, karpós, “fruit”; Latin: dracō from Greek: δράκων, drakōn, “dragon”). In the scientific literature, Dragon's blood tree species was first described by the Scottish botanist Sir Isaac Bayley Balfour in 1888 [16].

The best contemporary distribution of *Dracaena* forests and woodlands was published by Král and Pavliš in 2006 [17] using remote sensing data. They found that the habitats hosting *D. cinnabari* comprised a total of 7230 ha (hectare), including only 230 ha of *Dracaena* forests and 800 ha of mixed mountains forests, with the rest of the area (6200 ha) consisting of woodlands with low tree densities and overmatured populations [18, 19]. Based on statistical analyses as well as on direct field observations, Král and Pavliš also commented that the *Dracaena* populations on Socotra do not regenerate to a great extent, and their age structure indicates over maturity.

Attorre et al. in 2007 used a deterministic regression tree analysis (RTA) model to examine environmental variables related to the current *D. cinnabari* species distribution. They found that the current distribution and abundance of *D. cinnabari* is correlated to three factors: moisture index (i.e., the ratio between the annual precipitation and potential evapotranspiration), mean annual temperature, and slope. According to this model, *D. cinnabari* occupies only 5% of its current potential habitat, and this potential habitat is expected to be reduced by 45% by 2080 because of a predicted climate change, with increased aridity [10].

A study by Madera et al. in 2019 using remote sensing data estimated the population size of *D. cinnabari* to be 80,134 individuals, with sub-populations varying from 14 to 32,196 individuals, with an extinction time ranging from 31 to 564 years (**Figure 8**) [5].

A toponym study by Al-Okaishi (2021), carried out in four areas on Socotra Archipelago (301 toponyms), assumed that dragon's blood trees had a wider

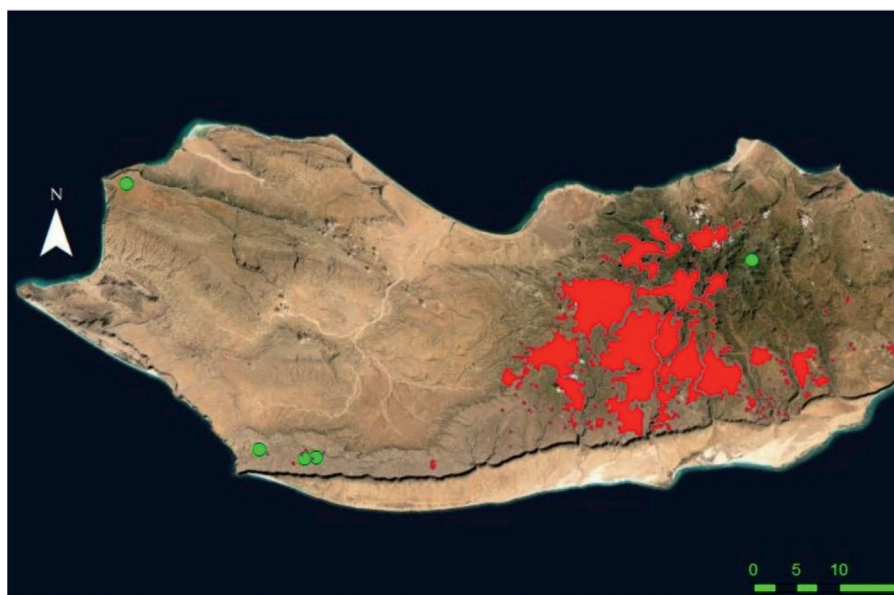


Figure 8.
The map of the distribution of the toponyms related to the *D. cinnabari* tree (green circles) in Socotra Island, in red, the current distribution of *D. cinnabari* by Maděra et al. [18].

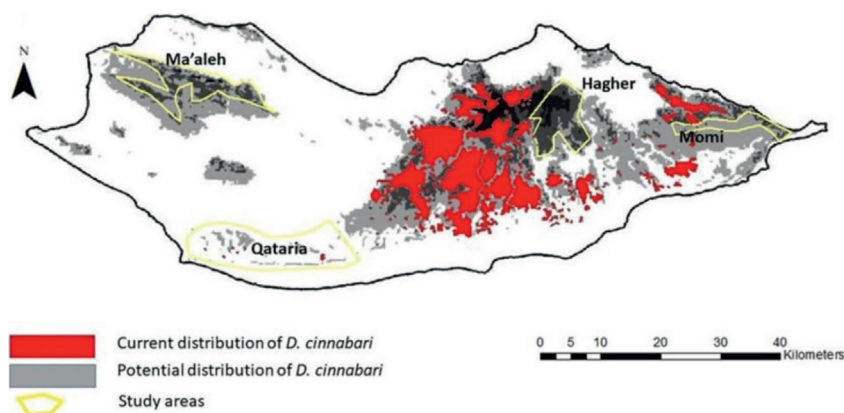


Figure 9.

Map showing the study areas (Hajher, Momi, Qatanin, Ma'aleh) in integrating two maps with the current and potential distribution of *D. cinnabari* according to Madëra et al. [5] and Attorre et al. [10], respectively.

distribution on Socotra Island in the past, potentially from the west in Ma'aleh to the east in Momi, before humans inhabited the island (**Figure 9**), [20].

In 2021, Vahalík et al. (published 2023) did a field survey of Socotra using a pair of UAVs (using the DJI Mavic Mini drones) to spatially describe individual tree positions, tree density, mortality, and the forest age structure. They found that the spatial distribution of the *Dracaena* tree density within the entire plateau is variable. The mean age of the forest, based on crown age (derived from crown size), was estimated at an average of ca. 300 years (291.5 years), with some individuals older than 500 years [21].

1.5 Dragon's blood tree conservation status

Due to its remarkable and highly vulnerable island ecosystems containing many endemic species, Socotra Archipelago was designated as a UNESCO Man and Biosphere (MAB) Reserve in 2003, a Ramsar Site in 2007 (Detwah Lagoon), and then as a UNESCO Natural World Heritage Site in 2008.

Dragon's blood tree (*D. cinnabari*) is categorized as "vulnerable" species on the IUCN Red List of Threatened Species (**Figure 10**), [22].

1.6 Dragon's blood (resin) and its significance

Since antiquity, Socotra Island was famous for its Dragon's blood, which is a remarkable bright red colored resin produced by *D. cinnabari*.

The name Dragon comes from the unique, red-colored sap or resin/latex that the tree produces. The tree is known locally as "Ahrieb" "إعريه" and its resin "dum al-akhawin" "الأخوين دم", while derived (mixed-cooked) products are called "eda'a" "إيدع", while regionally different names can be found (**Figure 11**), [23].

Local legends say that the Dragon's blood tree (brother's blood tree) first grew on the spot where two brothers, Darsa and Samha, fought to death. The Dragon's blood (red resin) is mentioned in early literature by an unknown author of the Periplus of the Erythrean Sea around the mid-first century AD, who called it "cinnabar," possibly because of the matching color [24].

Dioscorides in 90 AD mentioned the Dragon's blood resin in his book "On Medical Material" as Kinnabari "cinnabari," brought from Africa [25]. Names of Dragon's

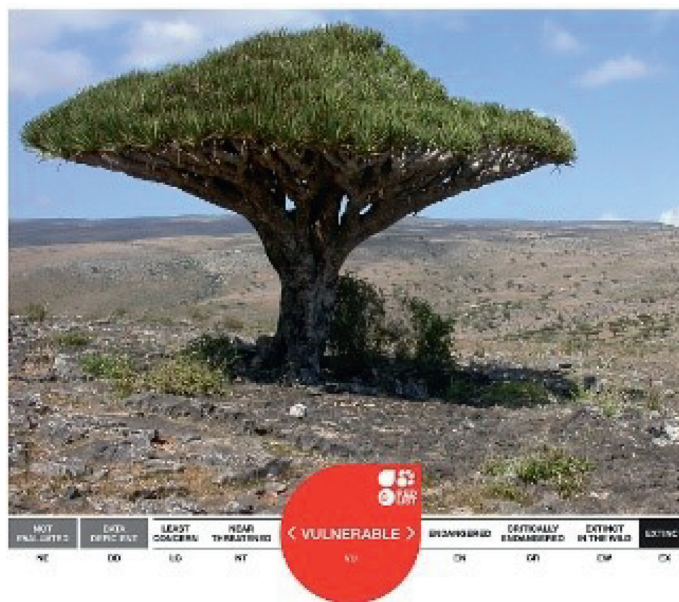


Figure 10.
 IUCN red list aims to convey the urgency of conservation issues to the public and policy makers, as well as help the international community to reduce species extinction.



Figure 11.
 The Socotra ecosystem and *D. cinnabari* species are unique to the island, with high global significance. (photograph by the author, Socotra 2018).

blood tree and its resin are also mentioned in old Arabic literature by travelers and researchers who visited Socotra in earlier days [26–29].

This highly prized resin has been historically harvested by the indigenous population for local use and trade throughout medieval periods for diverse medical, artistic,



Figure 12.

The Dragon's blood is a common name of a red sap, or resin, produced by the Dragon's blood tree in response to mechanical trauma. (photograph by the author, Socotra 2018).

and magical uses. It was frequently used as a medicine for respiratory and gastrointestinal problems in the Mediterranean basin and by early Greeks, Romans, and Arabs [30–32].

Miller and Morris mention the use of *Dracaena* resin as a coloring matter for varnishes, tinctures, toothpastes, and plaster for dyeing the horn to make it look like tortoiseshell [1].

Dragon's "blood" secretion (**Figure 12**) can be considered an induced natural defense mechanism following trauma by cells of the stem, and during the process of wound repair, this coats the margins of the wound providing additional protection against desiccation, but unfortunately, it also makes the species vulnerable to human exploitation.

Dragon's blood has astringent effects and is frequently used as a hemostatic and antidiarrheal medicine. Though the biological basis for its secretion and phytochemistry is still not completely known, the resin is believed by some authors to have antiviral, antibacterial, antifungal, antioxidant (flavonoids), and anti-carcinogenic properties [33–36]. Local inhabitants still use the red resin for treating diarrhea, fever, mouth ulcers; to stop bleeding; for wound healing, skin diseases, coloring material for dye, varnish, cosmetic, incense, painting, decorating earthen pots, folk music, alchemy, and performing social rituals. However, the efficacy for human use remains unsubstantiated and needs further bioassay-guided spectroscopic studies and scientific trials for establishing human safety and use.

Presently, this resin is an important product for the local communities and is the most important local nontimber forest product (NTFP). It is a source of income for the rural population in Socotra and is becoming even more important with the increasing population, unemployment, and tourism-related activities [20].

1.7 Dragon blood tree mounting challenges and extinction risk

The factors threatening the survival of Dragon's blood tree population envisage multiple reasons including overgrazing by the increasing population of livestock [10, 37]; habitat loss with insufficient regeneration of *Dracaena* growth; soil erosion;



Figure 13.
Dragon blood trees (D. cinnabari)—Socotra's most iconic plant. (photograph by the author, Socotra 2018).



Figure 14.
Uprooted Dragon's blood tree (photo by author, Socotra 2018).

increased aridity [10]; effect of past cyclones, namely Chapala and Megh (2015) and Mekunu (2018); climatic changes due to global warming; unsustainable human interference, which are not only rendering the *Dracaena* woodlands vulnerable to extinction [9] but also making the fragile biological hotspot vulnerable to desertification (**Figures 13 and 14**).

2. Discussion

The Archipelago of Socotra remained inaccessible for centuries due to its remote geographic location. This prolonged period of geological isolation of the archipelago, a complex geopolitical landscape, and variable climatic conditions with an arid ecosystem contributed to the maintenance of Socotra's distinctly rich biodiversity, with the preservation of many insular species like Dragon's blood tree for centuries.

However, the last few decades have threatened the fragile Socotra ecosystem due to multiple factors including woodland fragmentation, senescent dragon tree population, unsustainable harvesting of dragon's blood, unsustainable overgrazing, unsustainable livestock management, commercial collection of wood, introduction of invasive alien species, smuggling out of endangered Dragon's blood tree, climatic threats, uncontrolled infrastructure development including roads to the mountains, increased unsustainable tourism, lack of financial resources, non-diligent enforcement of international and national policies for bio-cultural preservation, current political instability, and post Covid-19 economic challenges.

The cattle (specially by goats) overgrazing of the vegetation including Dragon tree seeds is an important factor threatening the survival of the Dragon tree [1]. Consumption of seedlings and new sprouts, if not protected from goat and other livestock, prevents *D. cinnabari* and other species from regeneration as they have extremely low survival capacity in open habitats [10, 11]. Overgrazing also provokes soil erosion by causing loss of perennial vegetation layer and the thin organic topsoil following rains. The decline of *D. cinnabari* is likely to negatively affect plant diversity, reduce the abundance of rare endemic plants, and lead to homogenization of the vegetation [38]. The increasing demand of the red resin has resulted in the overexploitation of Dragon's blood tree and is one of the crucial factors adversely affecting the *Dracaena* population. The unsustainable traditional method of harvesting dragon's blood further compounds the deleterious effect on the *Dracaena* population [20]. Multiple cuts on tree to harvest resin invariably makes trees weak and vulnerable to uprooting in intense winds.

Another concerning factor is that most Dragon's blood trees on Socotra Island are senescent, with increasing mean population age and are subject to progressive *Dracaena* population decline due to limited natural regeneration of the species (Figure 15).

The loss of each Dragon's blood tree leads to a decrease in biodiversity, as Dragon's blood trees are important nurse tree [38]. Furthermore, the occurrence of a wide range of insect species depends on *D. cinnabari* [39]. Moreover, dragon's blood tree woodlands function as cloud forests, catching water from horizontal precipitation, fog, drizzle, and mist, playing a significant role in the hydrology of the island [40]. A decline in the Dragon's blood tree population density leads to land aridification, soil erosion, and desertification [41]. Given its ecological importance, *D. cinnabari* has been identified as an umbrella species of Socotra Island, with its conservation essential to preserve the island's native biota [10, 18, 39–43].

Socotra has a dry arid climate, with bimodal distribution of rainfall. The climate is dependent on the seasonal migration of the Inter tropical Convergence Zone (ITCZ) and related monsoon cycles [44]. Each year, from June until September, the seasonal Southwest monsoon blow from Africa brings hot, strong, and dry winds and occasional rainfall into Haggier mountains in Socotra. The Northeast monsoon in winter (November–January) is less pronounced and coincides with the rainy season in the north. The annual rainfall ranges between 200 mm in the coastal plains and 1000 mm



Figure 15.
Senescent Dragon's blood tree (photograph by the author, Socotra 2018).

in the high mountains [37]. The alternance of extreme desiccation and mist, brought about by the seasonal wind, had an important effect on the evolution of habitats and vegetation of the Socotra Island.

The climatic changes linked to global effects due to global warming are adding new challenges on the resilience of the vulnerable ecosystem. The resultant unreliable, irregular, and patchy monsoons with mean annual precipitation ranging from 207 to 569 mm is negatively influencing the survival of the present population of *D. cinnabari*. This is not only threatening Dragon's blood tree populations but also endangering other endemic species on Socotra Island. Global warming is perceived as a serious threat to the biodiversity of such hotspots because it is likely to exacerbate both grazing and prolonged drought periods due to unreliable monsoons making it exceedingly difficult for the recovery of vulnerable species [45, 46].

Increasing aridity due to ongoing climatic change is also negatively affecting the potential habitat of the Dragon's blood tree. The loss of Dragon's blood trees is also affecting the hydrological cycle as these plants capture horizontal precipitation [47].

There is also evidence that in the past, a traditional agricultural land use with protected wall system was prevalent on Socotra for organized farming activities for frankincense, myrrh, and dragon's blood and harvesting of aloe juice [48]. This strong traditional land-use management practices employed by the indigenous population served to protect the vegetation and biodiversity of the Socotra Archipelago, which is now lacking.



Figure 16.

Asphalt roads to mountains causing habitat fragmentation and ecosystem destruction. The future road works must minimize environmental impacts on the ecosystem. (photograph by the author, Socotra 2018).

The strict conservation of vulnerable areas included in the Socotra Archipelago Master Plan envisioned in 2002 are now not being enforced on Socotra due to administrative issues and a complicated land tenure system based on the tribal organization of society [5]. The lack of EIA enforcement capacity with deficient project planning and construction of new infrastructure including housing and several hundreds of kilometers of asphalt roads to mountains (since 2003) are also adversely affecting the fragile habitat of Socotra (**Figure 16**).

Other major threats are the increase in tourism and recreational activities, smuggling of Dragon blood trees to sell them in international markets, increasing immigration, import of goods from mainland Yemen, and pollution by deficient waste management practices around human settlements [20].

The archipelago's remarkable integrity and Outstanding Universal Value (OUV) is also significantly threatened by the unsustainable developments. There are no effective controls in place at the airport or ports to control the import of species and EPA has limited capacity to enforce such controls. Though there is a ban on the removal or export of Socotra flora and fauna, there are many reported incidences of smuggling out of rare endemic species, including Dragon's blood tree, affecting the biodiversity of Socotra Island. Due to ongoing regional instabilities, the coordination between major stakeholders regarding biodiversity conservation issues and decisions may also be affected. The current sociopolitical and post-Covid economic trends are also negatively impacting the site's capacity to provide sustainable economic growth for its people. The local government has limited financial resources and limited protective capacity to enforce local protective legislation. Thus, the population of Dragon's blood tree is thinning from forests to woodlands, shrublands, and eventually grasslands, with individual sparse trees.

Conservation of vulnerable and endangered endemic species depends on long-term strategies, coordination between different agencies, committed international funding, and involvement of the indigenous population with realistic developmental models; otherwise, money is being wasted with no changes on the ground, affecting the biodiversity more than before. A sustainable financing strategy also needs to be formulated to ensure necessary human and financial resources for the long-term preservation of the endangered ecosystem. More studies, planning, and appropriate linkages need to be developed and evolved for the management of the ecosystem, its buffer zones, and Socotra Biosphere Reserve. Awareness and educational activities to the natives emphasizing the fragility of islands and extinction risks are crucial. By involving the local communities and promoting them to take the lead in conservation activities by inculcating conservation knowledge and perpetuating it to the future generation, the inevitable negative impacts on biodiversity and livelihoods could be countered with improved ecosystem resilience. The local legislative laws for conservation need to be strengthened, maintaining a delicate balance among biodiversity preservation, sustainable trade, tourism, and infrastructure development. The careful implementation of these strategies is likely to positively impact the future of the endemic species in the Socotra archipelago.

3. Recommendations for the preservation of the Dragon's blood tree population

As the vulnerable biosphere reserve faces new challenges, we propose the following recommendations to protect and conserve the vulnerable Dragon's blood tree population and Socotra's unique archipelago biodiversity [5, 20, 21, 49–51]:

1. Propagating and protecting Dragon's blood tree by:

- Ecological restoration of Dragon's blood tree species in a protected environment, including local specialized nurseries for providing scientific expertise, technical assistance, and funding to the local inhabitants for the care of the saplings. This will help in the ecological restoration of native Dragon's blood tree communities, even if it takes many years for vulnerable trees to grow to maturity (exceptionally slow growing, around 2.65 cm over a five-year old period).
- Developing concept for a certified sustainable community forestry system, establishing a forest nursery to produce tree seedlings from local tree species population.
- Encouraging natives for setting good practice example even at the smallest scale, by planting and nurturing a single sapling of Dragon's tree in their garden.
- Protecting existing Dragon's blood tree and seeds from being used as fodder for livestock, firewood, and domestic use like house construction.
- Protecting aging Dragon blood trees from natural calamities with strategies focusing in-situ conservation.

- Promoting sustainable land management practices to enable Dragon's blood tree regeneration.
 - Protecting the existing Dragon's blood trees from human interference including unplanned infra-structural development/roads to mountain.
 - Promoting use of UAVs (drones) in collecting crucial data and creating a drone inventory for evaluating the conservation status and threat assessment of Dragon blood tree and other vulnerable species in the Socotra ecosystem.
2. Preserving Dragon tree habitat fragmentation and woodland degradation from overgrazing by feral and domesticated goats and other cattle.
 3. Promoting sustainable harvesting of Dragon's tree blood.
 4. Taking initiative for curbing soil erosion, increasing ecosystem resilience, and addressing threats from unsustainable resources to the ecosystem.
 5. Protecting and insulating the native ecosystem from invasive alien species (IAS) by biodiversity monitoring system, with emphasis on an early warning system with appropriate checks for invasive alien species.
 6. Strengthening of the sea port and airport biological monitoring to avoid smuggling out of endangered Dragon's blood tree species.
 7. Strict enforcement of the Socotra archipelago's protected area regulations and developing buffer zones in a complementary manner in Conservation Zoning Plan (CZP).
 8. Extending the boundaries of the strictly protected Skund nature sanctuary (where no (road) infrastructure is allowed) to include areas of Dragon's blood tree population.
 9. Enactment of local legislative laws and governance including Environmental Impact Assessment (EIA) and project approval prior to further infra-structural development and road construction.
 10. Maintaining a registry with proper data compilation, processing, and management, with regular monitoring of Dragon's blood tree population and distribution by regional centers.
 11. Formulating and improvising the existing master plan for sustainable infra-structural developmental activities with controlled sustainable development plans for preserving the island's Dragon's blood tree population.
 12. Increasing environmental awareness in the local population and strengthening local conservation efforts by employing adequate workforce.
 13. Educating, involving, and empowering the local population about the need for protecting the vulnerable Dragon's blood tree species and Socotran heritage.

14. Developing models that can assess and help in improving the chances of survival of endangered Dragon's blood tree species.
15. The development of nature-based tourism development program (Ecotourism).
16. Strong and effective collaboration among different stakeholders (from individuals to institutions).
17. Strengthening local legislative laws for conservation, aided by a strong political will to protect, preserve, and promulgate the archipelago's unique species.
18. Lastly, a sustainable financial strategy needs to be formulated to ensure long-term preservation of this flagship species.

4. Conclusion

Socotra's biodiversity remained resilient for centuries; however, the last two decades have threatened the well-preserved ecosystem including the vulnerable endemic Dragon's tree population. The strategic, result-oriented biodiversity preservation approach along with consideration of the proposed recommendations will not only help in protecting the Socotra's unique biodiversity from present and future challenges but also serve as a benchmark for biodiversity conservation around the globe.

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Conflict of interest

The author declares no conflict of interest.

Video materials

"Video materials referenced in this chapter are available at: {<https://bit.ly/3Dx92h6>}"

Author details

Sanjay Saraf
NMC Specialty Hospital, Dubai, United Arab Emirates (U.A.E)

*Address all correspondence to: drsaraf@hotmail.com

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