The Marula tree: An untapped Potential for Combating Desertification and Enhancing Socio-Ecological Resilience in Global Drylands

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Introduction

Marula, *Sclerocarya birrea* (*S. birrea*) (A. Rich.) Horchst is a drought-tolerant fruit tree which is of economic, nutritional and ecological importance, used and recommended for agroforestry and drylands restoration. However, there is global paucity of information regarding where its subspecies can survive in global drylands, and their potential for agroforestry. The study was conducted to predict and map global-scale suitable areas where *S. birrea* subspecies can be cultivated, conserved, and used to restore global drylands under the current and future climates, and explore their potential for agroforestry in drylands.

Material and methods

- Areas were modelled and predicted by using Maximum Entropy (MaxEnt) machine learning algorithm software and maps were developed by using ArcGIS 10.8 software.
- At global-scale, areas under the current climate (1981–2010) were modelled by using occurrence data for from Africa (Fig. 1) obtained from Global Biodiversity Information Facility (GBIF) and RAINBIO databases, and field surveys in Tanzania, and high-resolution 30-arc seconds (~1 km) bioclimatic and topographical variables from CHELSA and ENVIREM databases respectively.

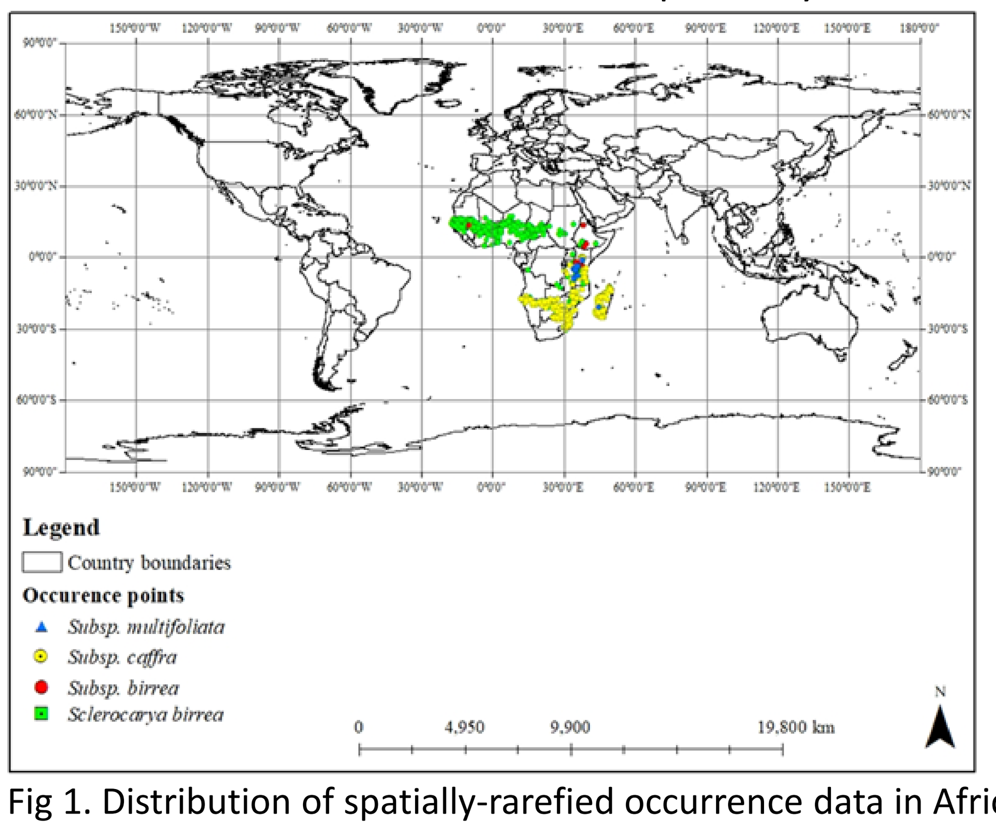

Fig 1. Distribution of spatially-rarefied occurrence data in Africa

- Future projections under the shared socio-economic pathways (SSPs), SSP3-7.0, for 2050 and 2080 were done by using the MPI-ESM1.2-HR and UK-ESM1.0-LL models.
- In Tanzania, areas under the current climate were modelled by using occurrence data from (GBIF) and field surveys in Tanzania, and high resolution (30-arc second ~1 km) bioclimatic, edaphic and topographical environmental variables from Woldclim, Africa Soil profiles, and NASA Shuttle Radar Topographic Mission (SRTM)-90m-digital elevation databases.
- Future predictions were done under two representative concentration pathways (RCPs) under greenhouse gas (GHG) emissions scenarios, the RCP4.5 and RCP8.5 for the years 2050 and 2080 by using HadGEM2-ES and CCSM4 Earth System models.
- Models performance was assessed by using areas under the curves (AUCs).
- Concentration of organic C, macro- and micro-nutrients in leaf and fruit litter samples from 27 randomly selected trees (nine for each subspecies) from Northen, Eastern and Southern Tanzania, was determined to assess potential for soil fertility improvement.
- Potential effects of *subsp. birrea* on drylands food crops was investigated through marula tree-sorghum experimental trials in North-western Tanzania.

Key findings

- Our models were robust with AUCs ranging from 0.90 to 0.98 at a global scale, and 0.85 to 0.94 in Tanzania.
- Suitable areas exist in all continents except Europe and Antarctica, occupy 3 751 057 to 24 632 452 km^2 of earth's terrestrial area in 54-107 countries, will retract by 64-100% under future climates and some regions of Eastern Europe will become suitable habitats, Fig. 2 &3.
- In Tanzania, suitable areas occur in 21-30 regions and occupy 28 446 to 184 814 km^2 which will contract by 0.4–44% under future climates, Fig 4-6.
- Soil under the canopies of *S. birrea* subspecies generally had higher nutrients concentration due to fruit and leaf litter than that away from the canopies, Fig.7 & 8(a)
- Sorghum plants grown under the canopies performed better and grains generally had numerically higher nutrients and minerals than those away from the canopies, Fig. 8(b)
- The fruit and leaf litter of *S. birrea* subspecies had carbon-to-nitrogen ratios (C: N), ranging from and 34.58 to 75.12
- The fruit litter of *S. birrea* subspecies generally had higher carbon and nutrients concentration than leaf litter, Fig. 7.

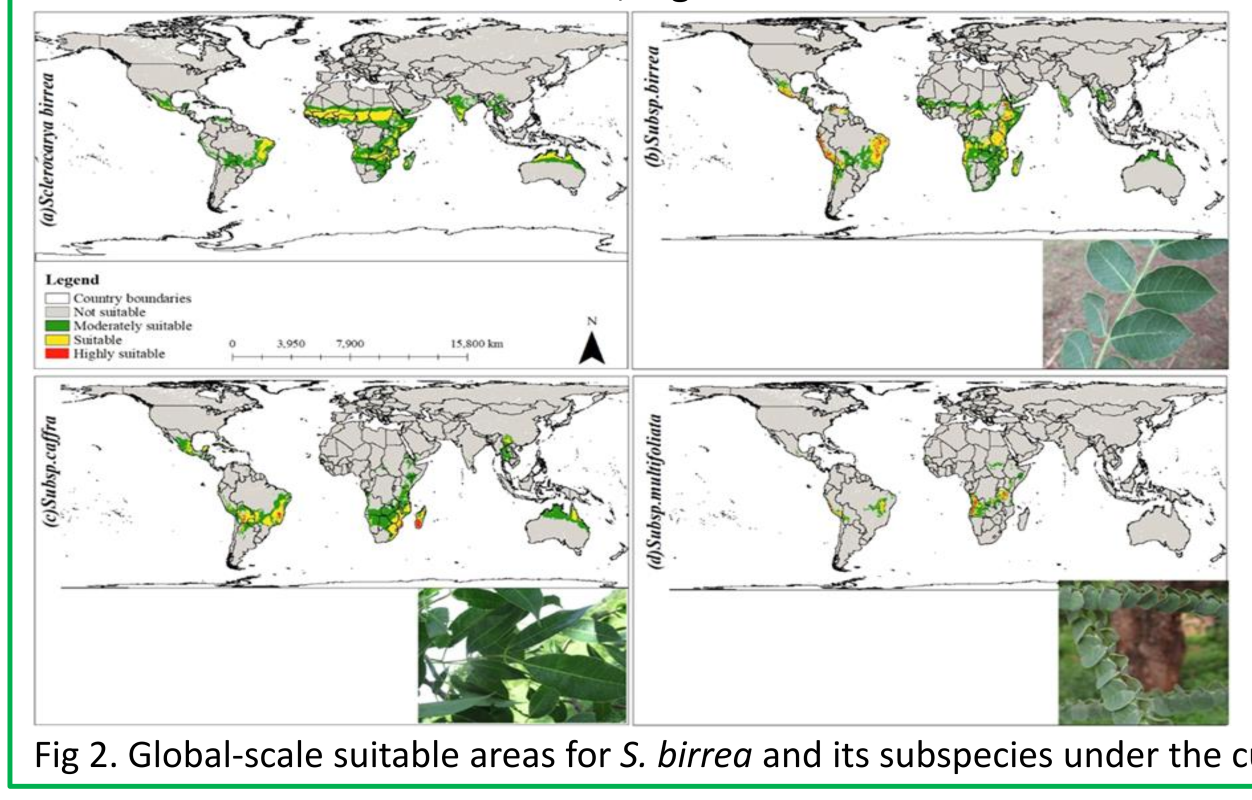

Fig 2. Global-scale suitable areas for *S. birrea* and its subspecies under the current climate.

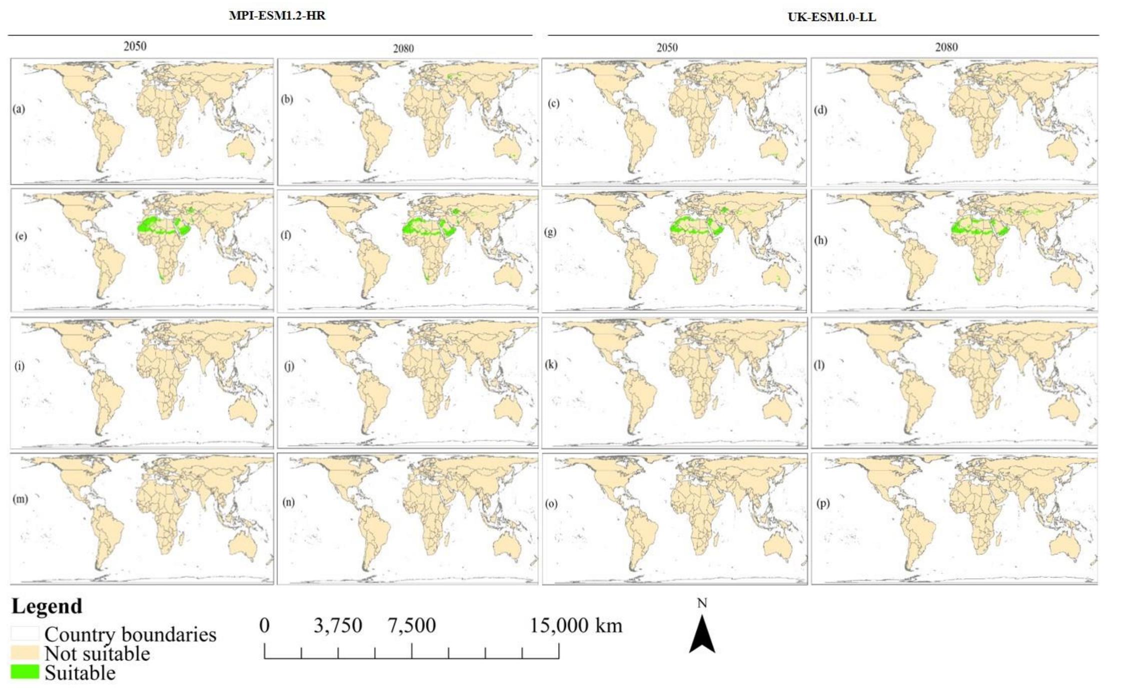

Fig 3. Global-scale suitable areas for *S. birrea* (a)-(d), subsp. *birrea* (e)-(h), subsp. *caffra* (i)-(l) and subsp. *multifoliata* (m)-(p) under future climates predicted by using MPI-ESM1.2-HR and UK-ESM1.0-LL Earth System models.

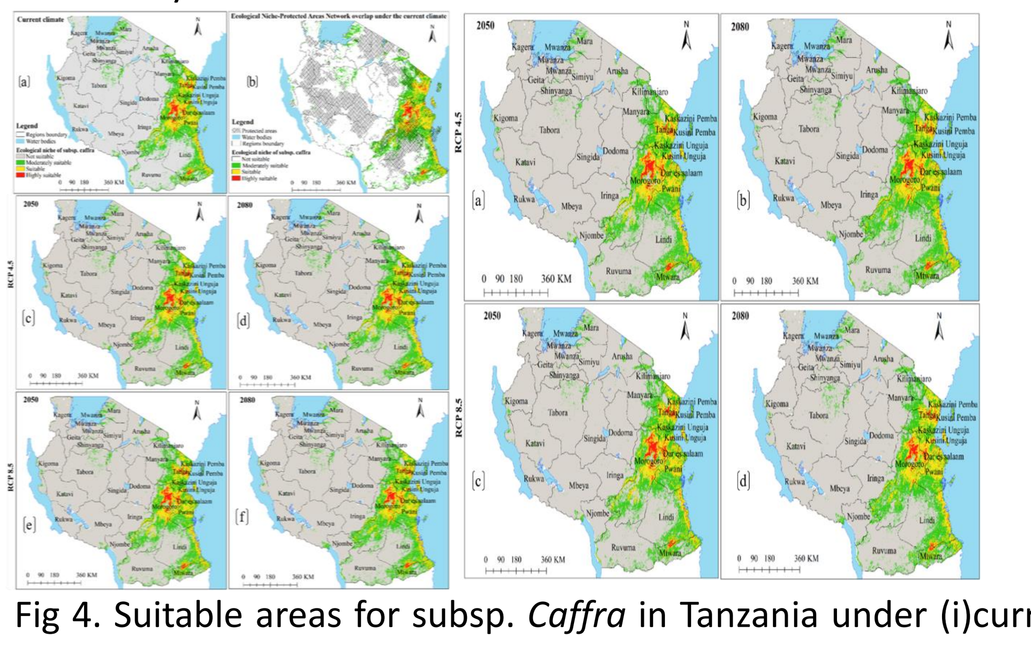

Fig 4. Suitable areas for subsp. *Caffra* in Tanzania under (i)current climate (a)-(b) and future climates as predicted under RCP4.5 and RCP8.5 by CCSM4 model [(c)-(f)] and HadGEM2-ES model [(a)-(d)].

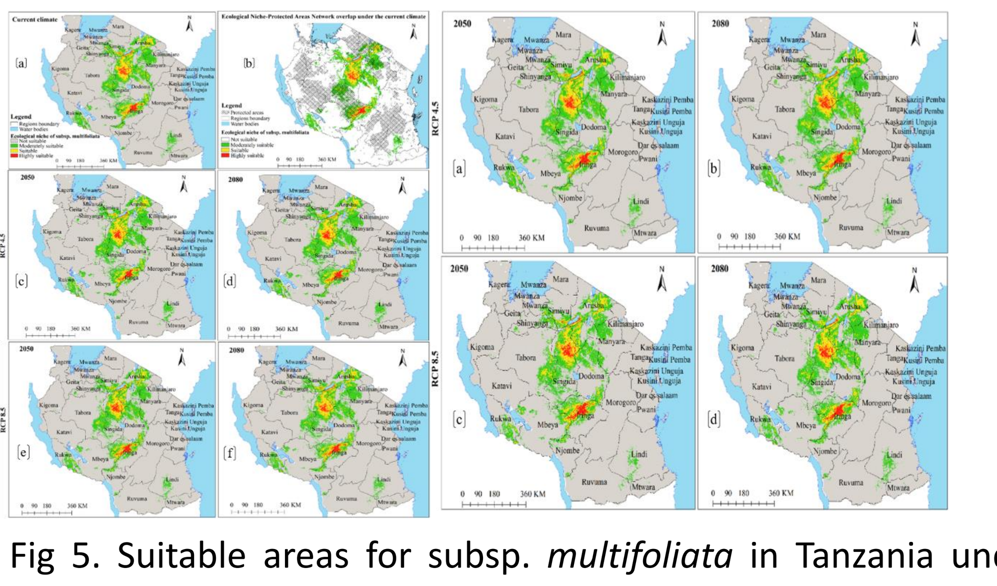

Fig 5. Suitable areas for subsp. *multifoliata* in Tanzania under (i)current climate (a)-(b) and future climates predicted under RCP4.5 and RCP8.5 by CCSM4 model [(c)-(f)] and HadGEM2-ES model [(a)-(d)].

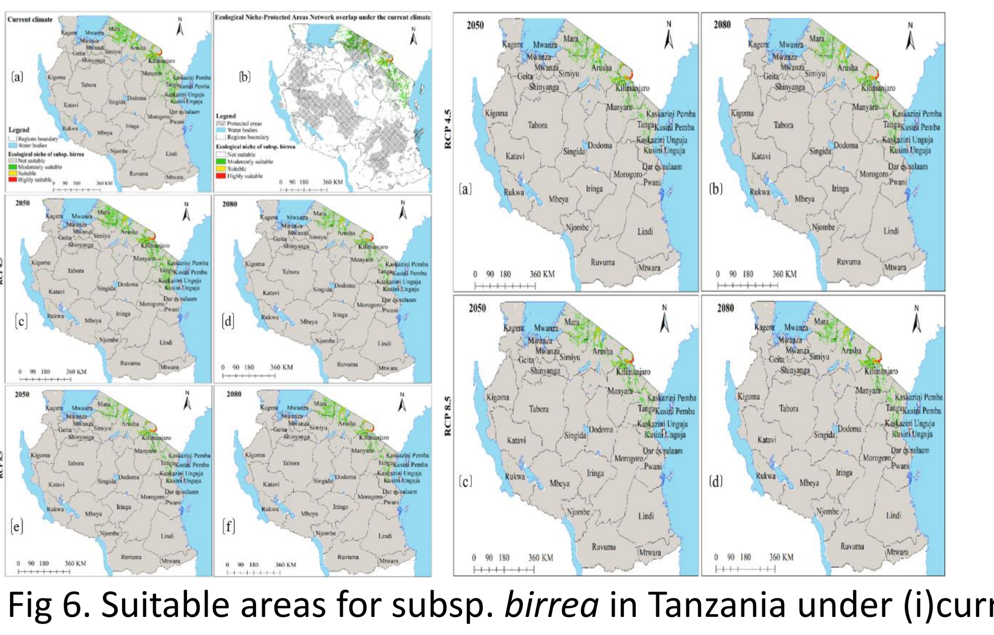

Fig 6. Suitable areas for subsp. *birrea* in Tanzania under (i)current climate (a)-(b) and future climates as predicted under RCP4.5 and RCP8.5 by CCSM4 model [(c)-(f)] and HadGEM2-ES model [(a)-(d)].

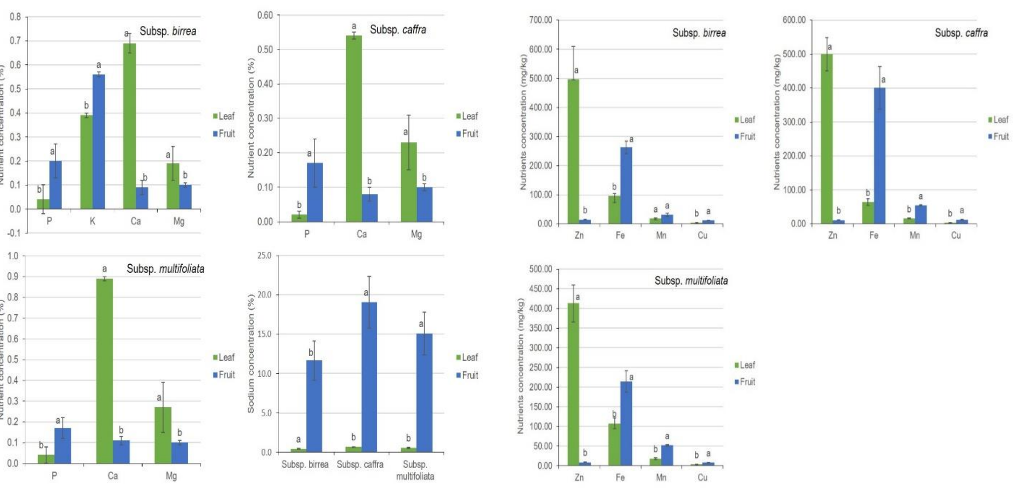

Fig 7. Nutrients concentration in *S. birrea* subspecies leaf and fruit litter. Error bars are standard errors of the mean (n = 9). Bars within subspecies and nutrients with different letters are significantly different at alpha = 0.05.

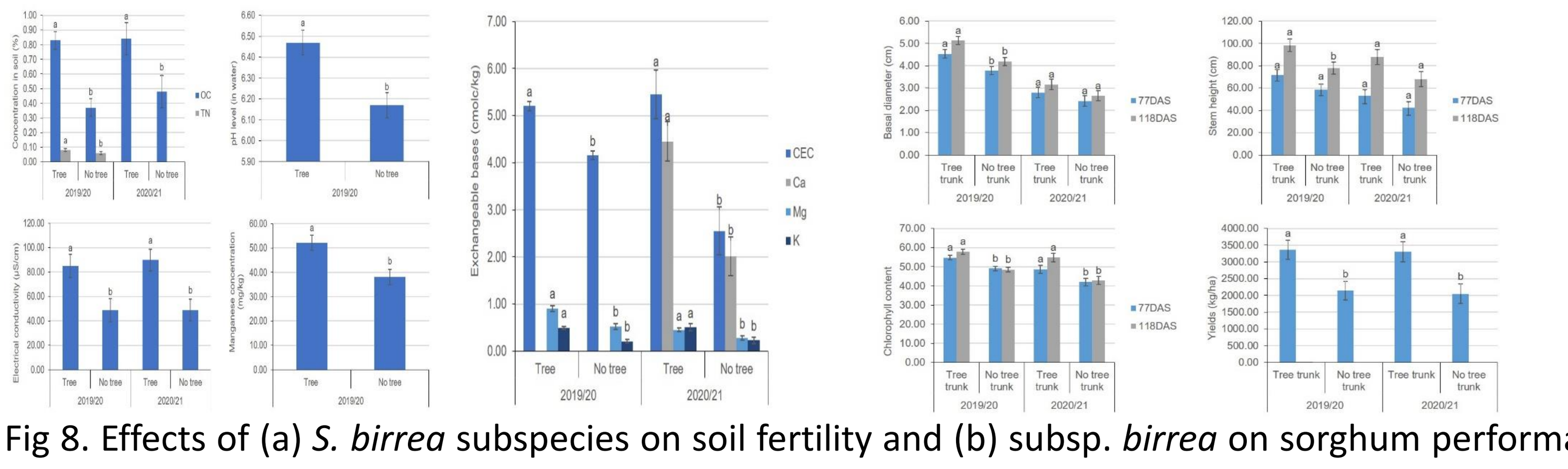

Fig 8. Effects of (a) *S. birrea* subspecies on soil fertility and (b) subsp. *birrea* on sorghum performance. Error bars are standard errors of the mean (n = 7). Bars with the same color and different letters within the year are significant different at apha=0.05; DAS, days after sowing.

Conclusions

- The *S. birrea* is a drought-tolerant tropical tree with potential to contribute in combating desertification and enhancing socio-ecological resilience in global drylands.