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Opportunities and applications of dendrochronology in Africa☆

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Partly due to severe lack of instrumental climate data, the drivers of the African climate, their interactions and impacts are poorly understood. The paper demonstrates the prospects and applications of dendroecological and stable isotope techniques, such as to reconstruct climate variability, trends and atmospheric circulation patterns, to fill the knowledge gap in ecosystem productivity and hydrological cycle in different climatic zones of Africa. We summarize the contribution of tree-ring analyses to validation of climate and hydrological models for improved scenarios, and to identify agroforestry species with the ability to acclimate to exacerbated climate conditions. A high number of African tree species shows datable annual tree rings and may reach multi century age. To advance dendrochronology in Africa, collaborative efforts in capacity building of African universities and research organizations are needed.

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Introduction

Dendrochronology is the discipline of dating tree rings to the year of their formation and using exactly dated tree rings for detecting environmental signals that are common for a population of trees. Basics, principles and wider applications of dendrochronology are well described [1], and history and recent progress of tropical dendrochronology is documented in recent reviews [2,3]. In the last decades, the potential of stable-isotope signatures of carbon, oxygen, hydrogen, nitrogen in tree rings has been unravelled and applied to questions addressed in ecology, physiology and climate change studies [4].

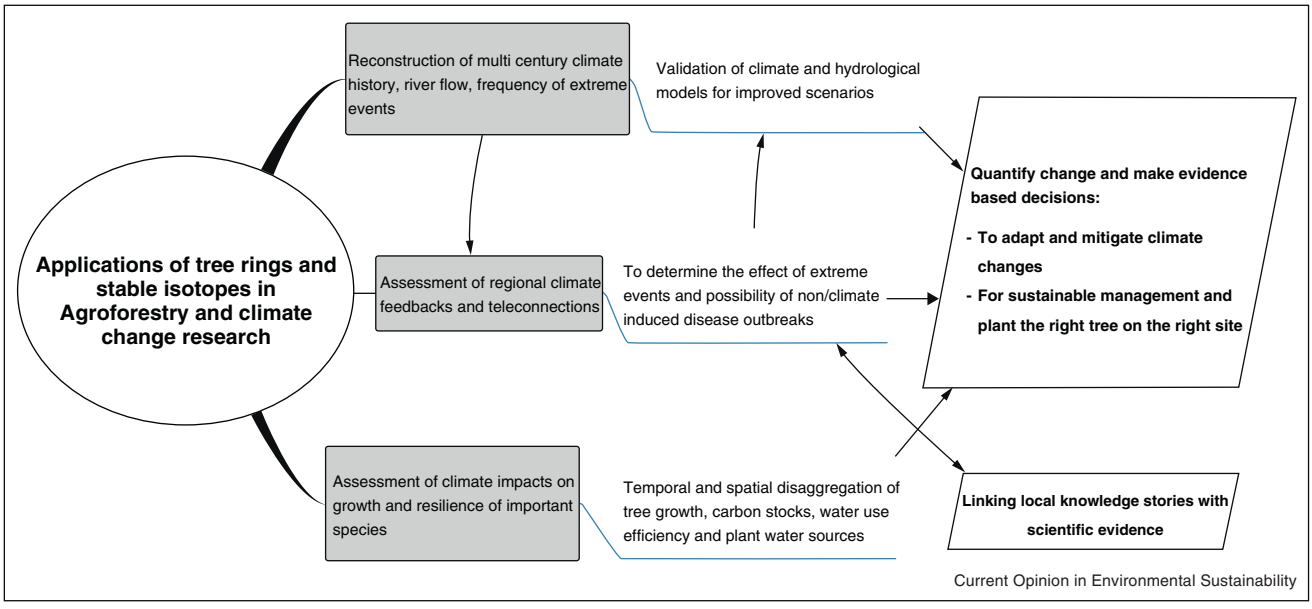
This paper focuses on dendrochronology in subsaharan Africa in general and its application in agroforestry/forestry and climate change research, in particular (Figure 1). Although dendrochronological work in Africa is still in its infancy, it has wide potential. We will first point to the challenges of tropical dendrochronology and will delve into how unravelling the past responses of trees to climate would contribute to address the following issues:

(1) Because of a severe lack of instrumental climate records, the drivers of the African climate, their interactions and local and global impacts are poorly understood.
(2) Potential changes in the hydrological cycle due to global warming may lead to negative impacts on food security and livelihoods in Africa.
(3) In Africa, knowledge on growth and population dynamics, the range of natural climate variability and the range of tree species tolerance to climatic extremes is scarce. This information is crucial for sustainable natural forest management and to support decisions in agroforestry and reforestation efforts.

Challenges and opportunities for dendrochronology in the tropics

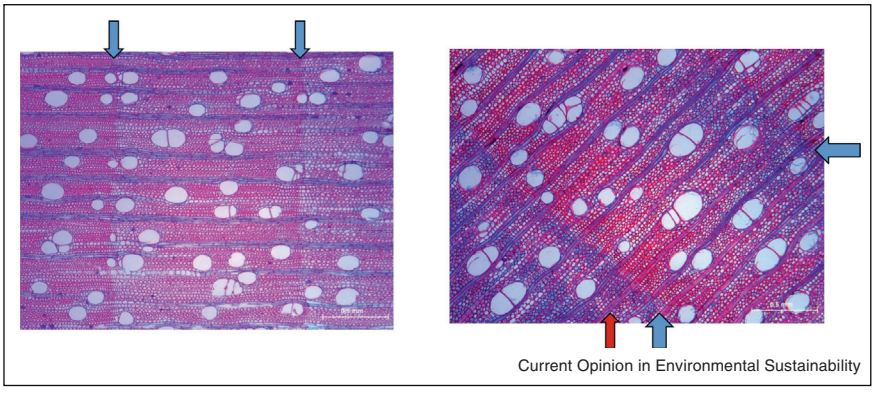
The presence of anatomically distinct, annual growth rings is the prerequisite for the development of correctly dated ring-width chronologies. Formation of distinct growth boundaries requires periods with growth limiting environmental conditions, which induce growth stops in trees (=cambial dormancy) [2,5]. In the tropics where seasonal changes in temperature are generally low and frost occurrence is limited to higher-elevation areas, growing seasons are mainly defined through precipitation changes (drought in dry areas and flooding in floodplains) [2]. Deciduous species are more likely to form growth rings than evergreen species. Under optimal conditions, radial growth can prevail all year long [6] but the probability for the formation of distinct growth rings increases with the climate seasonality. The major problems in applying dendrochronology in Africa are indistinct,

Figure 1



Possible applications of tree rings and stable isotopes in agroforestry and climate change research in Africa.

Figure 2



Site dependent double ring formation a major challenge of dendrochronology in tropics. Arrows indicate ring boundaries **(a)** Microsections of *Sclerocarya birrea* from Burkina-Faso Sahel region, showing very distinct annual rings because of clear climate seasonality **(b)** Microsections of *Sclerocarya birrea* from Tanzania, where formation of false rings is evident in some years in the form of intra annual density variations because of biannual rainfall and/or drought during the growing season (the red arrow shows a false ring boundary).

double (Figure 2), missing or wedging rings and are summarized by [6].

However, with the advancement of technology and emerging new methods during recent years the prospect for dendrochronology in Africa is considerable. For instance, regular microcoring of the cambium and microscopic analysis of the cells formed between sampling intervals (e.g. [7]), and dendrometer measurements [8,7] provide information on cambial dynamics, seasonal growth and sensitivity to climate variability. Intra-annual stable isotope ratio measurements have revealed seasonal cycles that can potentially be employed to date tree samples without distinct anatomical ring boundaries (e.g. [9,10••]). Linking tree ring analysis with remote sensing techniques (e.g. seasonal NDVI measures) may provide additional information on the start, end, and length of vegetation periods [11]. Thus, general judgements if tropical trees do form annual tree rings or not should be replaced by more differentiated views under which climate conditions growth rings are formed in an individual species (Figure 2) and what kind of measurements are necessary under specific site conditions.