doi.org/10.22498/pages.30.1.40

Socio-ecological vulnerability and adaptation of southwestern Malagasy to changing environment and climate

Estelle Razanatsoa and Lindsey Gillson

In the face of a changing environment linked to increased drought and depletion of natural resources, paleoecological data of the last 2000 years show how communities in southwestern Madagascar adopted both incremental and transformational adaptations that allowed them to cope with environmental variability.

SW Madagascar: a case study illustrating a global challenge

Dealing with the consequences of climate change on Earth requires conserving the world's biodiversity, while managing ecosystem services sustainably. Sustainability requires meeting the needs of current and future generations, and keeping open their options to adapt (United Nations 2015). Understanding landscape history can help to determine what is sustainable in a changing environment, while understanding adaptations of past societies may provide stakeholders with a more solid basis for dealing with future changes (e.g. Razanatsoa et al. 2021).

This approach is particularly important in climate hotspots as these areas will experience higher magnitudes and rates of change in the near future (United Nations 2015). Vulnerability to future climate change is exacerbated in areas such as southwest Madagascar, where natural resources are already being depleted (Razanatsoa et al. 2021). Southwest Madagascar is known for its arid climate, receiving less than 500 mm per year of rainfall on average. The region is currently experiencing recurrent droughts that are predicted to become more extreme in the future (Waeber et al. 2015; Masson-Delmotte 2021).

Climate reconstructions show variable climate conditions in Madagascar, with evidence of drier phases over the last 2000 years (Vallet-Coulomb et al. 2006; Virah-Sawmy et al. 2016). Multiple lines of evidence have pointed out changes in ecosystems in the region responding to this climate variability (e.g. Godfrey et al. 2021; Razanatsoa et al. 2022; Virah-Sawmy et al. 2016) but also to land-use change as a response to environmental change. Increase in grass abundance was recorded around 1 kyr BP and the near present time, both linked to changes in land use particularly with the use of fire (Razanatsoa et al. 2021). In these landscapes, humans have adapted to changing climate both "incrementally", i.e. through an extension of activities to their existing livelihood, or adopting a more "transformational" approach, i.e. with shift from one form of activities to another (Kates et al. 2012).

Contrasting livelihood strategies

Southwest Madagascar is presently occupied by agropastoralists and forager communities. Agropastoralism dominates around Longiza, while foraging is still prevalent near Tsizavatsy (Fig. 1). Over the last 2000 years, these communities have adapted their livelihood in response to environmental change and economic growth (Razanatsoa et al. 2022).

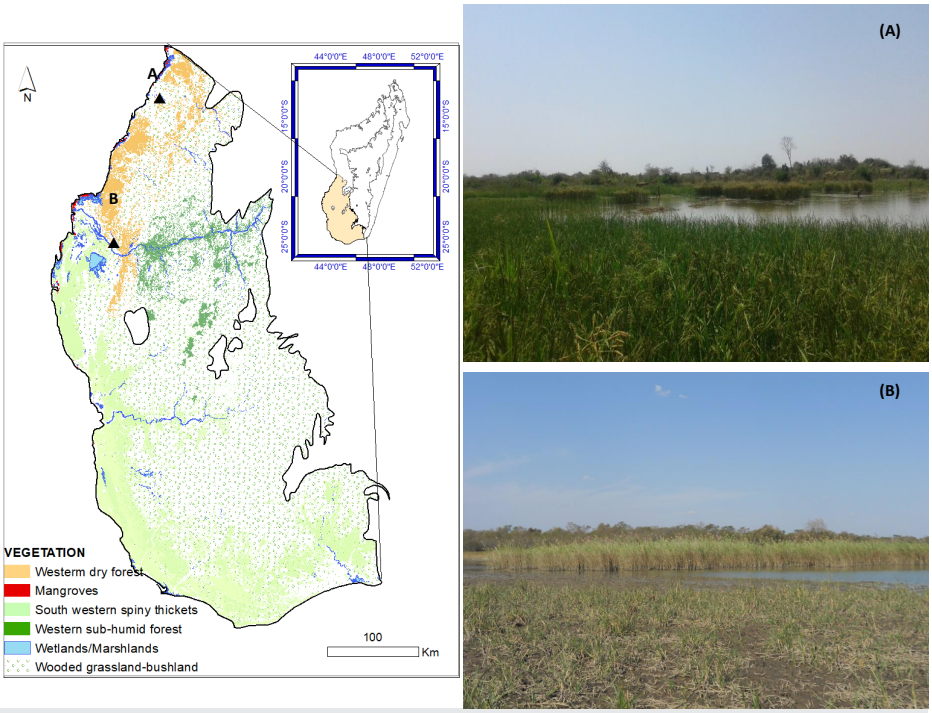

Figure 1: Southwest Madagascar's vegetation with the location and pictures of the sites investigated here: **(A)** Lake Longiza and **(B)** Lake Tsizavatsy.

The communities living around Lake Longiza currently practice agropastoralism as their main livelihood, but have shifted their subsistence strategies and livelihoods over time. Early occupants of the southwest region were probably foragers (Anderson et al. 2018). Increasing charcoal influx and coprophilous spore concentration (Fig. 2) suggest that fire has been used to support agricultural practices and pastoralism activities in the area since 600 CE (Fig. 1; Anderson et al. 2018). The first charcoal peaks at Lake Longiza are recorded around 1300 CE (microscopic charcoal) and 1500 CE (macroscopic charcoal), suggesting that pastoralism started around that time. Domestic cattle were introduced to the island of Madagascar around 700 CE, and expanded to the southwest by 1300 CE. Dung fungal spores reflecting the presence of herbivores likely indicate a shift in human practices from foraging to agropastoralism (Razanatsoa et al. 2022).

In contrast to the transformational shift in livelihoods near Lake Longiza, people near Lake Tsizavatsy have demonstrated a form of incremental adaptation in response to drying, and the associated changes in resources (Razanatsoa et al. 2021). Following a marked increase in fire activity at the beginning of the 20th century (Fig. 2), fire activity remained constant during the following decades, maintained by the current practices of swidden agriculture between December and March (Razanatsoa et al. 2021; Fig. 2). In response to the drying in their region, the Mikea communities living in southwest Madagascar reinforced their traditional practices of foraging (mainly used during the 13th century), and incorporated seasonal agriculture as a new coping strategy in the 20th century (Razanatsoa et al. 2021).

Local adaptations to drying climate

Paleorecords from the region indicate massive environmental changes (e.g. Razanatsoa et al. 2022). Around Lake Longiza, the communities abandoned their initial foraging practices to become agropastoralists (Razanatsoa et al. 2022). Such a transformation was likely possible because the region is currently known to have higher sources of water through river systems, more fertile

soils (compared to the south), and is supported by international trade.

Such a shift was probably not possible around Lake Tsizavatsy because of the less fertile soils with unconsolidated sand (Seddon et al. 2000), and the more arid conditions. As a result, a complete abandonment of foraging is less likely at Lake Tsizavatsy, as water availability is too unpredictable to sustain permanent agropastoralism. Thus, agropastoralism provides an additional livelihood when conditions permit, but foraging remains important, especially in years that are too dry to support crop cultivation. Although experiencing a decreasing trend of rainfall and recurrent drought, the adaptation of these two communities depended entirely on local environmental conditions.

The aforementioned factors including the change in land use and climate variability have contributed to changes in the vegetation in southwest Madagascar. Increase in Poaceae (ca. 51% to 65%) suggests an opening of ecosystems around 1900 CE linked to agropastoralism around Lake Longiza (Razanatsoa et al. 2022), likely at the expense of a more diverse and heterogeneous landscape. With changing climate conditions, evidence of increasing dry-adapted plants is recorded around 1000 CE and 1700 CE (Razanatsoa et al. 2022). In particular, these led to a decrease in natural resources for the early forager communities and the need for new subsistence strategies at the expense of the local biodiversity.

Outlook

More challenges for food production, and, thus, food security, are expected for the African continent under a 1.5°C global temperature increase accompanied with increased drought in arid and semi-arid regions (Serdeczny et al. 2017; Masson-Delmotte 2021). Paleoecological data show that the decline and shift in vegetation associated with a reduction in ecosystem services such as fuel wood, sources of food, and medicine for these resource-dependent communities will lead to changes in human livelihood (Razanatsoa et al. 2022). Previous shifts in subsistence strategies have been attributed to factors including (but not limited to) the arrival and expansion of pastoralism and international trade.

While agropastoralism continues to expand with the growing population in Madagascar, the capacity of landscapes to sustain this is finite. In addition, a decrease in rice and maize production is projected in tropical regions under a +2°C scenario, making such practices less sustainable (Challinor et al. 2016). With these projections, current livelihoods will become more challenging, requiring more transformational and incremental adaptation. However, adaptation strategies should consider biotic and abiotic components of ecosystems in order to maintain the ecological infrastructure that will ultimately sustain the survival of its people. These last forager communities are likely to be forced into a larger shift in their livelihoods as they become more vulnerable (Razanatsoa et al. 2021), highlighting the need for more diversified livelihoods. This could be achieved through the participation of local and national stakeholders in formulating coherent adaptation strategies to enhance the resilience of forest-dependent communities to a changing climate (Saalu et al. 2020) but also the establishment of self-organized local institutions within local and Indigenous communities (Berman et al. 2020).

These case studies reflect a broader context on how social and ecological dimensions of biodiversity conservation and climate change adaptation can be in conflict, and should be tackled together. Paleodata provides insight into what happened in the past and how various communities adapted their livelihood to past environmental changes, and provides a basis for exploring future scenarios. It is important to note that the challenges people and ecosystems are facing today are unprecedented. Such challenges can only be tackled through collaboration and integration of various forms of knowledge into scenario planning and policy, if both the quality of life and level of biodiversity are to be maintained in a changing world.

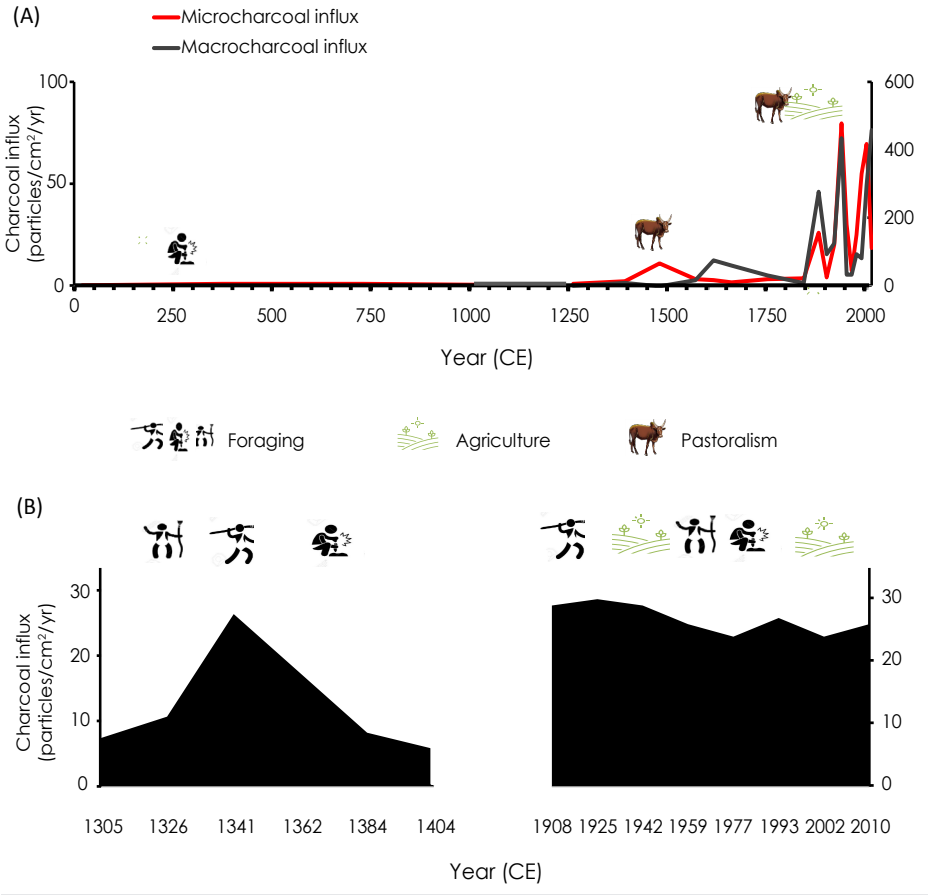

Figure 2: Fire variability inferred from charcoal records and associated livelihood practices. **(A)** Lake Longiza covering the last 2000 years (adapted from Razanatsoa et al. 2022); **(B)** Lake Tsizavatsy covering the 14th and 20th centuries (Razanatsoa et al. 2021).

ACKNOWLEDGEMENTS

We acknowledge support from a faculty PhD fellowship (University of Cape Town), the Applied Centre for Climate and Earth Systems Science (ACCESS NRF UID 98018), the University Research Committee (URC) accredited by the University of Cape Town, the NRF/SASSCAL (Southern African Science Service Centre grant number 118589), the NRF/African Origins Platform (grant number 117666), and the NRF Competitive Programme for Rated Researchers (Grant Number 118538).

AFFILIATION

Plant Conservation Unit, Department of Biological Science, University of Cape Town, South Africa

CONTACT

Estelle Razanatsoa: estelle.razanatsoa@uct.ac.za

REFERENCES

Anderson A et al. (2018) PLoS One 13: e0204368

Berman M et al. (2020) Clim Change 159: 1-16

Challinor A et al. (2016) Nat Clim Change 6: 954-958

Godfrey LR et al. (2021) Front Ecol Evol 9: 742203

Kates et al. (2012) Proc Natl Acad Sci USA 109 (19): 7156-7161

Masson-Delmotte V et al. (Eds) (2021) Climate Change 2021: The Physical Science Basis. Cambridge University Press, in press

Razanatsoa E et al. (2021) Malagasy Nature 15: 41-45

Razanatsoa E et al. (2022). Holocene 32: 57-69

Saalu FN et al. (2020) Int J Clim Chang Strateg Manag 12: 1-21

Serdeczny O et al. (2017) Reg Environ Change 17:1585-1600

Seddon N et al. (2000) Oryx 34: 287-304

United Nations (2015) Transforming our world: The 2030 agenda for sustainable development. UN Publishing, 41 pp

Vallet-Coulomb C et al. (2006) J Geochem Explor 88: 153-156

Virah-Sawmy M et al. (2016) Landsc Ecol 31: 637-654

Waeber PO et al. (2015) Int For Rev 17: 127-148