Disproportionate contribution of riparian inputs to organic carbon in freshwater systems.

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1. Introduction:

1. The riparian zone plays a key role in regulating the delivery of terrestrial organic matter to streams and rivers[1].

2. However, determining the origin of riverine carbon (C) at the landscape scale is often hampered by a lack of appropriate proxies distinguishing various landscape units and their constituent organic C (OC) pools.

3. Here, we explore riverine particulate and dissolved OC fractions (POC and DOC respectively) and the OC pool of riverine bed sediments in combination with their C stable isotope signatures ($\delta^{13}C_{POC}$, $\delta^{13}C_{DOC}$, $\delta^{13}C_{SED}$) as a function of bulk sub-basin vegetation $\delta^{13}C$ ($\delta^{13}C_{VEG}$) and soil $\delta^{13}C$ ($\delta^{13}C_{SOIL}$) signatures in the C_4 dominated Betsiboka basin (Fig. 1). For comparison, we also report results from the C_3 dominated Rianila basin (Fig. 1).

Fig. 1 (Right): Overview of Madagascar and the two river basins studied here (B = Betsiboka, R = Rianila).

3. Seasonal Riverine Organic Carbon Concentrations and $\delta^{13}C$ Compositions:

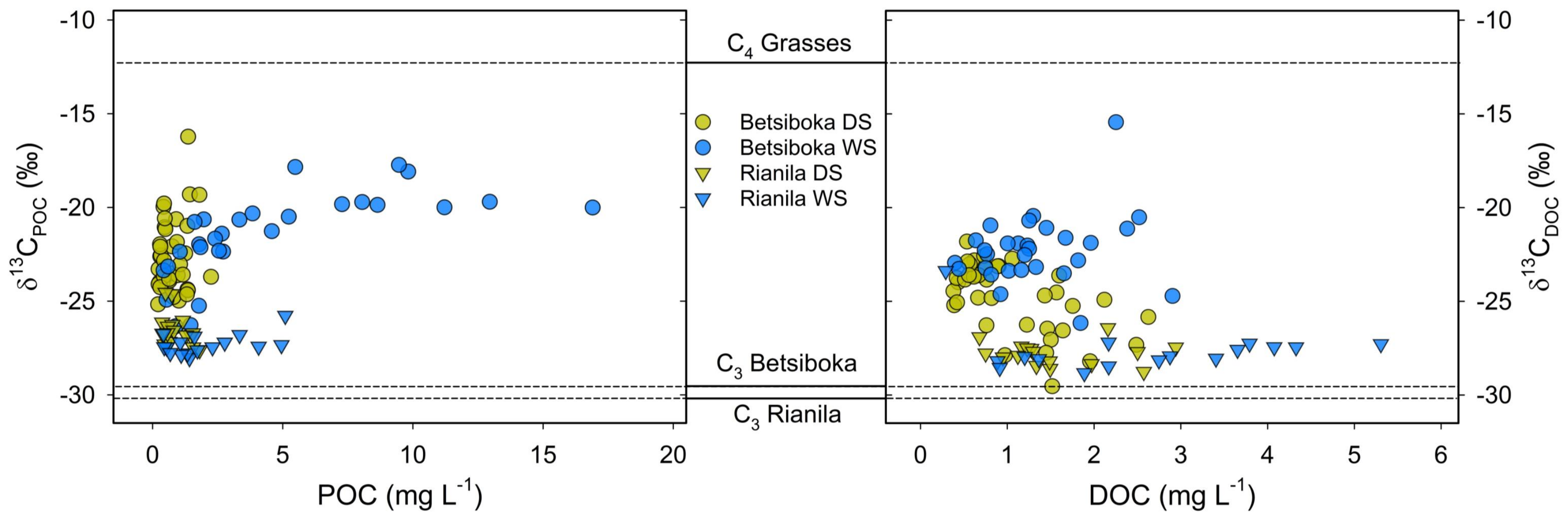

Fig. 4: Seasonal riverine OC concentrations and $\delta^{13}C$ signatures. The mean *DS* and *WS* $\delta^{13}C_{POC}$ values were -22.7 ± 2.0‰ and -21.4 ± 2.3‰ in Betsiboka basin and -26.5 ± 0.9‰ and -27.3 ± 0.6‰ in the Rianila basin.

1. During the *WS*, the mean riverine OC concentrations increased relative to *DS* (Fig. 4), with concurrent enrichment and depletion of ^{13}C in the Betsiboka and Rianila OC pools, respectively, representing increased influx of OM from the wider basin following elevated precipitation[3,4,5].

2. Terrestrial-derived OC dominates: (i) extremely low pelagic primary production rates, (ii) high mg POC: mg Chlorophyll *a* ratios (>1000), (iii) very low dissolved N + P concentrations, (iv) general lack of macrophytes in Malagasy streams and rivers[6].

2. Methodology:

1. Sampling of riverine OC pools carried out in dry and wet season (*DS*, *WS*) throughout the Betsiboka (sites: *DS*=37, *WS*=29) and Rianila (sites: *DS*=16, *WS*=16) basins.

2. Leaf litter (LL; from within and beyond the riparian zone) and surface soil (upper 5 cm) samples collected for $\delta^{13}C_{LL}$ and $\delta^{13}C_{SOIL}$ analyses.

3. $\delta^{13}C_{VEG}$ estimated by either: (i) extracting the basin area upstream of the sampling location from the vegetation $\delta^{13}C$ *isoscape* of Africa[2] (Fig. 2), and taking the average cell value, or (ii) extracting the basin area upstream of the sampling location from satellite imagery (Fig. 3), converting to greyscale and adjusting gamma so black pixels equal the C_3 end-member of $\delta^{13}C_{LL}$ (Betsiboka = −29.5‰; Rianila = −30.2‰) and all other pixels equal the C_4 $\delta^{13}C_{LL}$ end-member (−12.2‰).

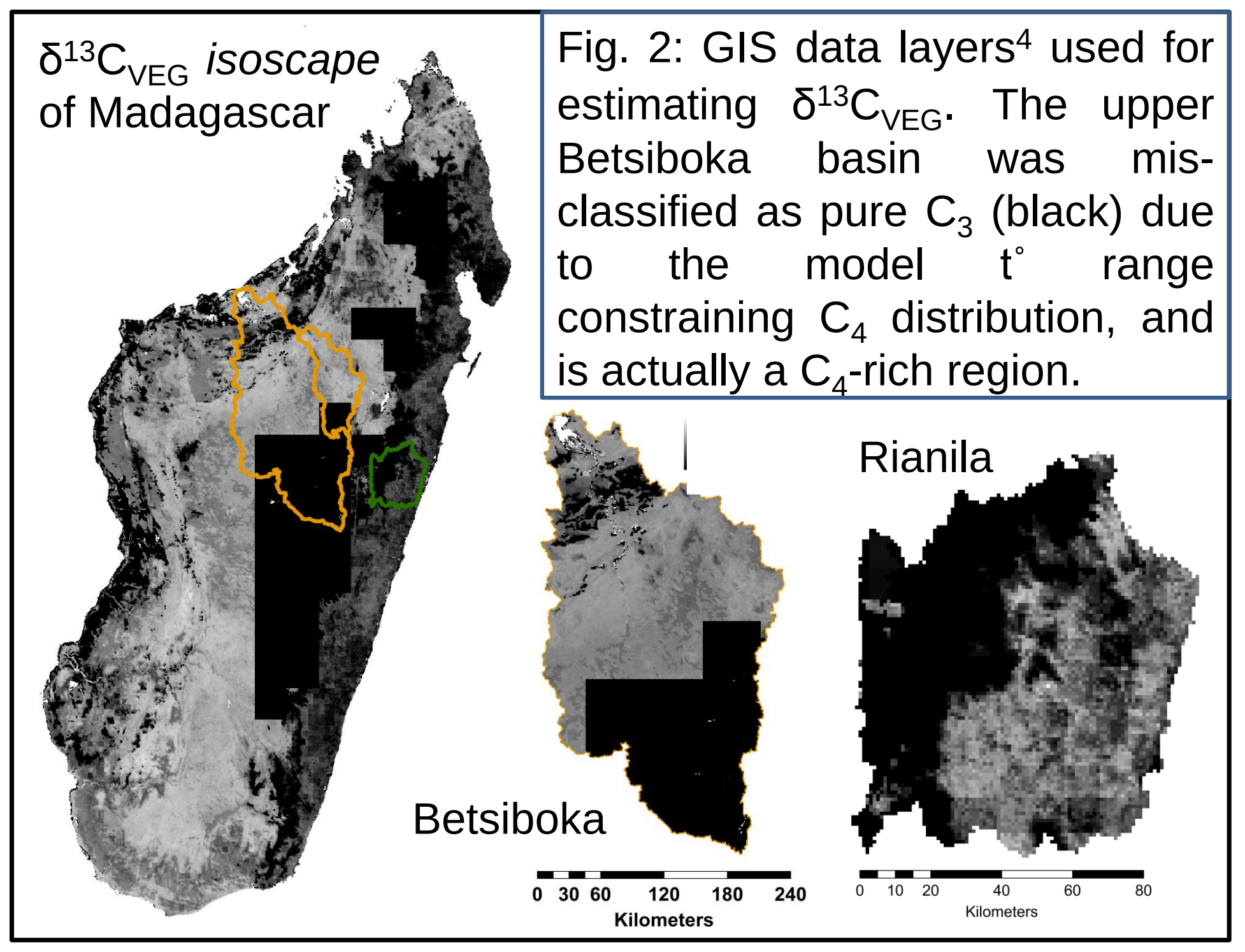

Fig. 2: GIS data layers[4] used for estimating $\delta^{13}C_{VEG}$. The upper Betsiboka basin was mis-classified as pure C_3 (black) due to the model t° range constraining C_4 distribution, and is actually a C_4-rich region.

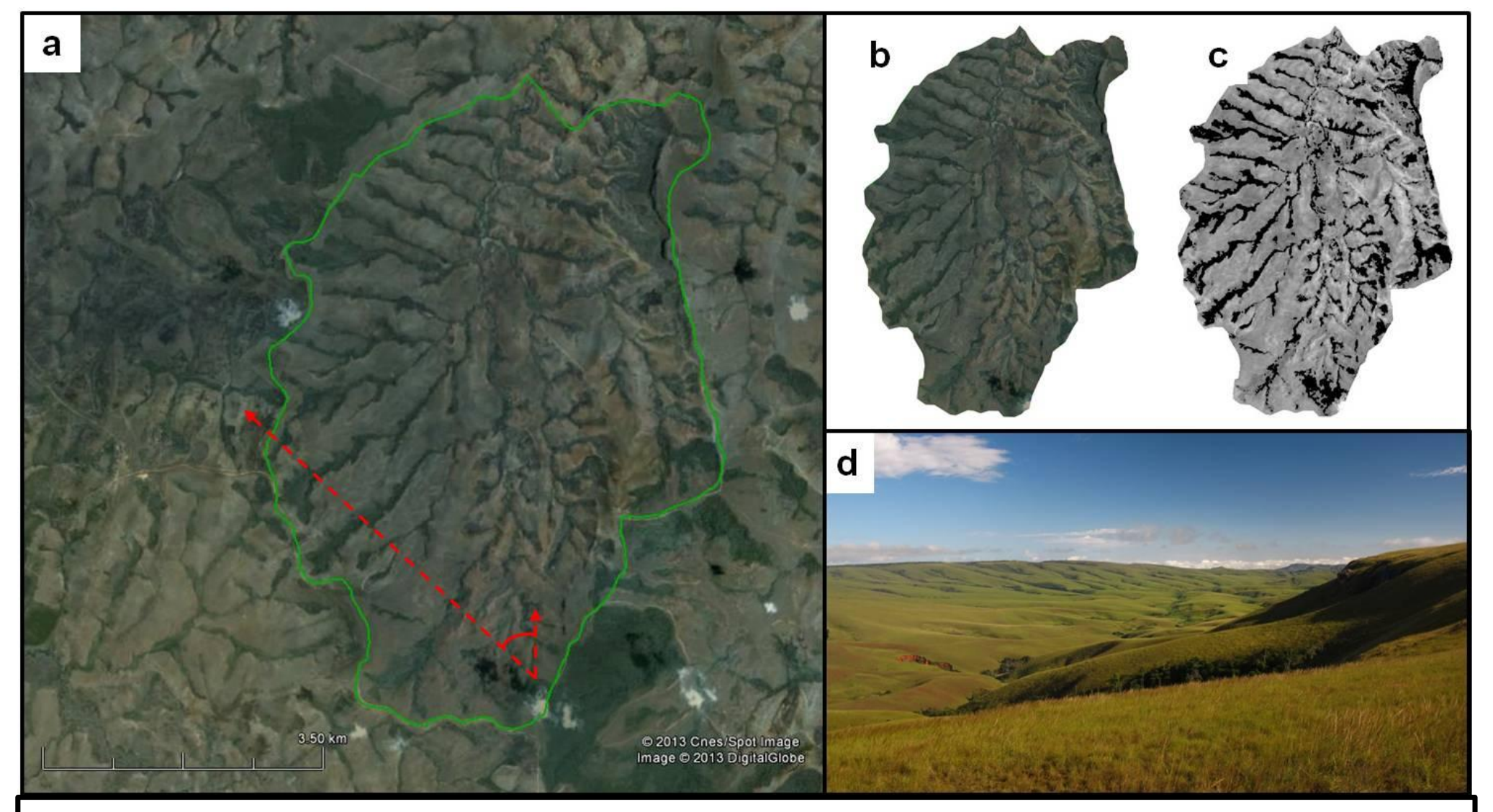

Fig. 3: Example of the technique for estimating $\delta^{13}C_{VEG}$ from satellite imagery, implemented for select Betsiboka sub-basins where C_4 land cover has been mis-classified in Fig. 2.

4. Disproportionate Contribution of Riparian OC:

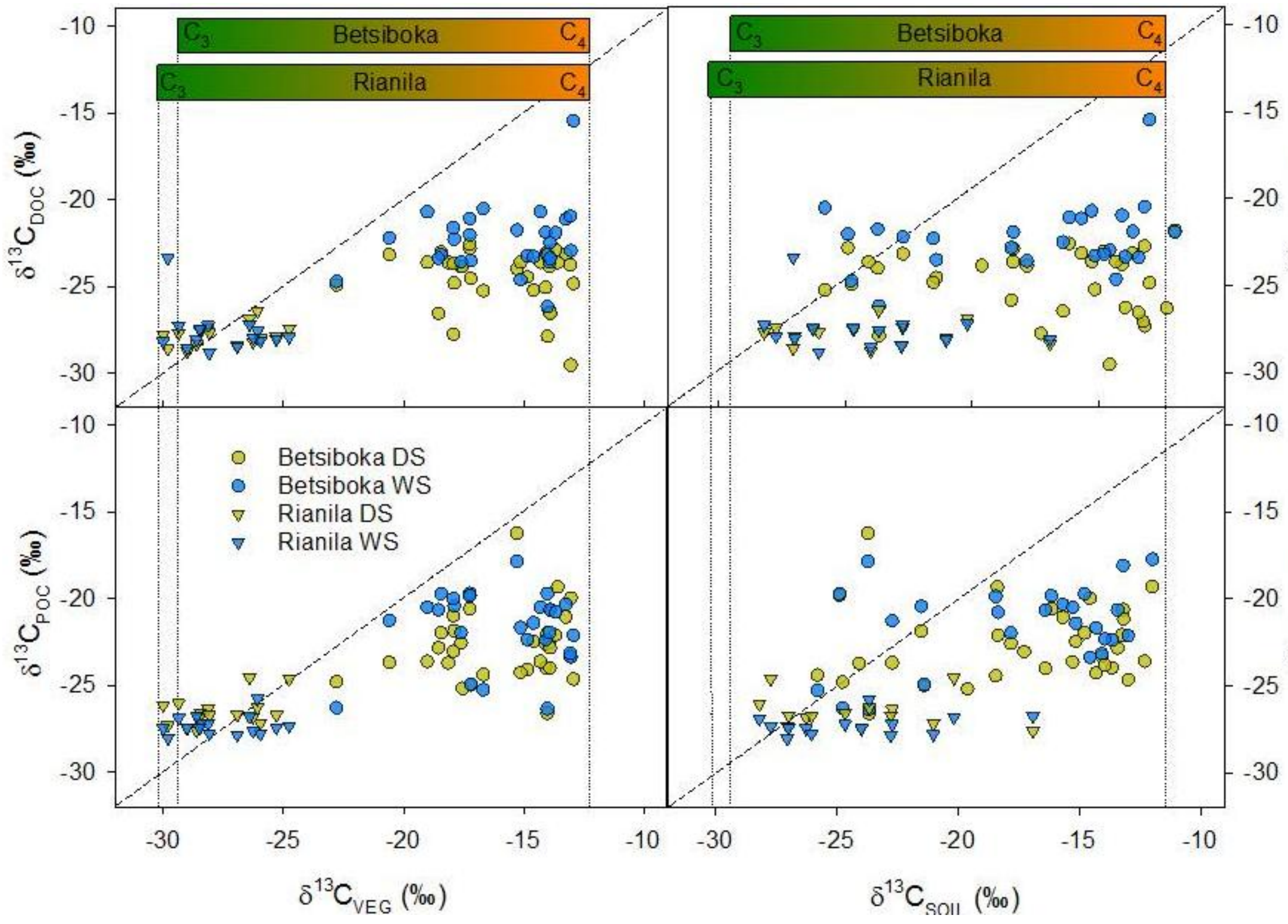

Fig. 5: Riverine (top) $\delta^{13}C_{DOC}$ and (bottom) $\delta^{13}C_{POC}$ signatures as a function of (left) estimated $\delta^{13}C_{VEG}$ and (right) $\delta^{13}C_{SOIL}$ signatures. Colour bars represent $\delta^{13}C_{LL}$ end-members for the C_3–C_4 gradient in each basin.

1. A clear pattern emerges, with Betsiboka DOC, POC and sediment OC all consistently more ^{13}C-depleted than expected across the C_3–C_4 gradient. These relationships are evident irrespective of whether riverine OC fractions are explored as a function of estimated bulk vegetation $\delta^{13}C$ or soil $\delta^{13}C$ (Figs. 5 + 6).

2. The relationship between soils and riverine OC is weaker than the latter with basin vegetation $\delta^{13}C$, though can be expected given that riverine $\delta^{13}C_{OC}$ measurements and $\delta^{13}C_{VEG}$ estimates aggregate across wide environmental gradients, whereas $\delta^{13}C_{SOIL}$ values reflect conditions at one spatially distinct sub-basin location.

3. $\delta^{13}C_{SED}$ values offer a more reliable indication of the mean $\delta^{13}C_{OC}$ transported in tropical river basins where longterm monitoring is not possible[7]. In the Betsiboka basin, there was on average a 6.9 ± 2.7‰ depletion of ^{13}C in $\delta^{13}C_{SED}$ signatures relative to paired $\delta^{13}C_{VEG}$ estimates (Fig. 6).

4. As much as ¼ to ½ of Malagasy grasslands may be burnt each year[8], which combined with estimates that annually African wildfires consume approximately 10% of savannah net primary production[9] (releasing CO_2 back to the atmosphere), suggests that fire significantly reduces the C_4-derived OC pool available for export to surrounding freshwaters[10], and therefore may be considered a secondary control on riverine $\delta^{13}C_{OC}$ composition.

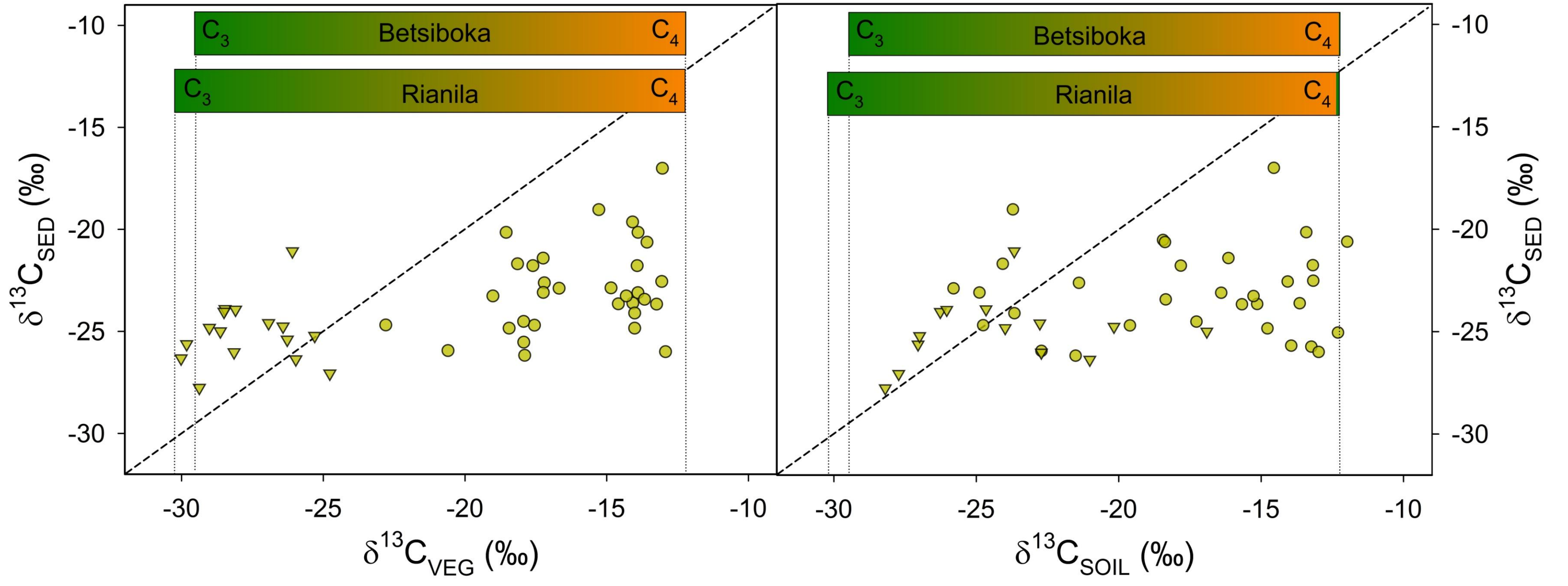

Fig. 6: Riverine bed sediment OC $\delta^{13}C$ signatures as a function of (left) estimated $\delta^{13}C_{VEG}$ and (right) $\delta^{13}C_{SOIL}$ signatures. See Fig. 5 for data symbology. $\delta^{13}C_{SOIL}$ and $\delta^{13}C_{SED}$ measured only during the dry season.

5. Conclusions

1. Riverine $\delta^{13}C_{OC}$ signatures are bias proxies for the relative proportion of C_3 and C_4 land cover in C_4-rich landscapes.

2. This observation cautions the interpretation of $\delta^{13}C_{OC}$ in sedimentary (i.e. lacustrine, near-shore marine) deposits as a valid proxy for paleo-vegetation distribution.

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