Making the Case for Research on TOF in Africa

1.0 Framing the Case for Measuring and Monitoring of TOF.

The World Agroforestry Center often notes that the "future of trees is on farms". This catchphrase reflects growing expert opinion that while forests world-wide are being converted and degraded, *tree cover* outside of forests may be increasing at a rapid pace, *especially in developing countries and in semi-arid agricultural landscapes*. In contrast to forest trees, trees outside forests (TOF) often are not included in the national monitoring of tree resources. Consequently, data about this particular resource is rare, and available information is typically fragmented across the different institutions and stakeholders that deal with one or more of the various TOF types. In the context of climate change mitigation and adaptation, international climate mitigation programs focus on forest trees without considering the impact of TOF, a consideration this study finds crucial if accurate measurements of regional tree biomass and carbon pools are required.

While biomass density is lower in TOF landscapes compared to forests, the large area and increasing stocks make these areas quantitatively important (for carbon sequestration, support to livelihoods, climate change adaptation, etc.). An important study across three continents by Schnell et al. (2015a, 2015b) of TOF data from 6 countries showed a significant amount of carbon stored in TOF systems. The question of increasing biomass in Africa is focused on semi-arid landscapes with mosaics of agricultural and natural, but heavily impacted, woodlands. The increases in biomass can be linked to two interrelated factors: 1) changes in precipitation regimes that favor tree establishment and growth and 2) farmer-promoted management of TOF in agroforestry and other tree-based systems.

Systems of trees outside of forests (TOF) include agroforestry complexes, small-holder plantations, orchards, energy farms and woodlots, hedgerows and shelterbelts, scattered individual trees and other woody perennial establishments in predominantly small holder agricultural landscapes. The utilization of trees on farms provides natural products and direct economic value to land managers as well as a range of indirect co-benefits, including water retention, increased site fertility and productivity, animal fodder, domestic energy from fuelwood and charcoal, biodiversity and more. TOF systems enable small-holders to create a diversified portfolio of products other than annual crops alone, *often with significantly higher economic value compared to annual crops*. TOF systems also sequester and store carbon and buffer against adverse impacts of climate change; increasingly TOF systems are an integral component of new strategies for climate smart agriculture.

The conventional wisdom for more than two decades has been to see LCLUC in Africa through a lens of agricultural expansion and concomitant loss of natural ecosystems. Moreover, land degradation is viewed as a dominant characteristic of agricultural land use in Africa. Arguably this model has been important and relevant to understanding global climate change and the carbon cycle as well as other global scale land science processes. However, when viewed against this backdrop we often overlook how significant an increase in tree cover in small holder agricultural landscapes is to our understanding of carbon sequestration, new transitions and drivers of LCLUC, and the needs of policy and development communities. The TOF question is central to understanding where and how natural ecosystem conversion trends and land degradation are being, *or can be*, reversed – with significant benefits to small-holders' livelihoods and their land productivity.

2.0 Increasing TOF as an Emerging Global LCLUC Hotspot Issue.

In reviewing the global distribution of systems of TOF, Zomer et al. (2016) offers an assessment of the importance of this land use transition. Their paper reviews the role of trees on agricultural land and its significance for carbon sequestration at a global scale, based on recent change trends. They report that in 2010, 43% of all agricultural land globally had at least 10% tree cover and that the area was increasing. Further they estimated that trees contribute >75% of agricultural carbon stocks and are increasing at 1% per year. Although carbon density is much lower than in forests, these landscapes are important because they cover a large area, and are marginal, climate change-vulnerable land with high population densities of agriculturally dependent communities.

These tree systems do not appear in most forest classifications, but they are an important carbon stock. There could be an extremely large area of tree cover that is outside of the land that is classified as 'forest' (Zomer et al., 2016). Between 2000 and 2010, there was a 2% increase in tree cover on agricultural lands globally, and 36% of Africa's land area had an increase in woody cover between 1992 and 2011 (Brandt et al., 2017a). Agricultural land is accumulating carbon through increased individual tree cover. The annual expansion of tree cover on agricultural land is storing an additional 740 Mg CO_2 per year on a global basis (Zomer et al., 2016); thus, agroforestry and other TOF systems could be offsetting greenhouse gas (GHG) emissions by over 0.7 billion tons $CO_2e\ yr^{-1}$ (Lewis et al., 2019). As a community, we should be looking closely at this LCLUC issue.

3.0 The Significance of TOF in Africa.

African agricultural landscapes are traditionally known for their use of tree systems to capture a range of ecosystem functions and also as a source of food, fiber, and energy. Many of the farming practices in Africa are tree-based systems that combine trees with land management practices for food and animal production. Across Africa, agroforestry has proven suitable for small landholder farmers and low income household economies, because the range of practices offer a source of livelihoods and a basis for local economies (Nair, 1993). In Africa, various forms of agroforestry have evolved, leading to complex high biomass typologies as described by Mbow et al. (2014) and Mbow et al. (2020).

In the humid forests of Africa, deforestation is an ongoing dominant land cover transformation process. However, tree-sparse African landscapes have been experiencing a pronounced greening trend over the past 30 years (Brandt et al., 2017b). While herbaceous vegetation has a high interannual variation, the greening trend seen in drylands is mainly caused by the woody layer, and it is largely driven by climatic factors -- for example as an increase in the frequency of heavy rainfall events and extra-seasonal rainfall (Brandt et al., 2017b, 2019; Zhang et al., 2019). At the same time, new studies are challenging the narrative of a singular negative correlation between human population growth and a decline in woody cover (Brandt et al., 2018, Mbow et al. 2020). Farmers in arid and semiarid Sahelian lands seem to *promote* medium-to-high woody cover in their fields, often even exceeding the

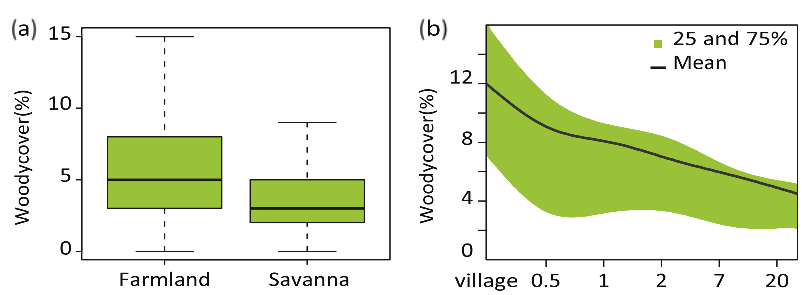

Fig. 1. Apparent increase in woody cover promoted by farmers in West Africa. a) Comparison between farm biomass and native biomass. b) Biomass decreases with distance from village areas. Source: Mbow et al. 2020, adapted from Brandt et al. 2018.

woody cover of the surrounding savannas (Brandt et al., 2017a, 2018, Mbow et al. 2020) (**Fig. 1**).

In the more humid regions, the transformation of savanna woodlands to farmlands results in an initial reduction of woody cover; however, the overall tree density in farmlands remains high. In the semi-arid regions of West Africa, farming landscapes contain higher woody cover than the native woodlands. Moreover, farmland trees take advantage of the reduced competition to grow larger than in the woodlands and savanna and are thus an important possible sink for carbon (Mbow et al. 2020). **Fig.1** shows the distribution patterns of trees in relation with the distance from settlements (Mbow et al. 2020). At the continental scale, most drylands have seen an increase in woody cover. Deforestation is mainly occurring in the densely and sparely populated zones of the more humid areas (**Fig. 3**).

Vegetation productivity in the Sahel has increased and it has led to net carbon uptake (Brandt et al., 2015). The increase in the strength of the carbon sink is largely driven by an increase in gross primary productivity during the growing season. An increase in precipitation in the July-August-September-October season has led to reduced drought and thus, to better growing conditions. At the same time, a long dry season in the Sahel does not mean there is no productivity during that period. Very resilient agroforestry trees (e.g. Acacia, Balanites, Shea, Ziziphus, etc.) are tapping into the water table during that season to sustain an accumulation of biomass over time—despite large effluxes during the dry season and transition periods—explaining an improvement in the net sink over the last 30 years (Dardel et al., 2014).

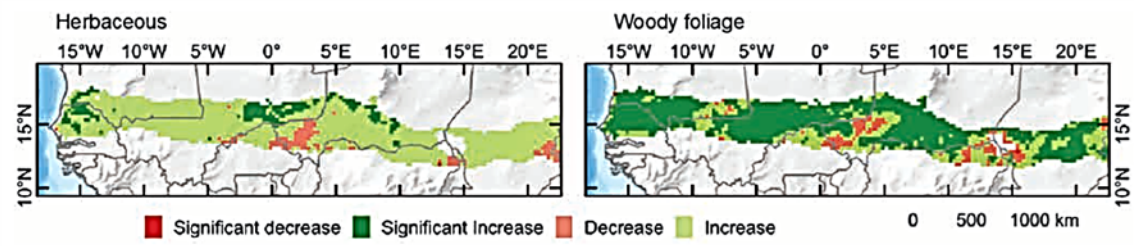

Fig. 2. Apparent increases in TOF-based biomass, mostly in the woody layer over herbaceous cover in West Africa. Source: Mbow et al. 2020, adapted from Brandt et al. 2018.

Tree cover on agricultural land is now 10–30% in sub-humid Africa. Most agricultural lands are suited to growing trees. Traditionally, farmers have managed the natural regeneration of trees on their farmlands. This practice is being adopted at an accelerating pace, and it is being supplemented by active planting of trees on farm and field boundaries and in crop fields (Mbow et al. 2020).The role of semiarid agroforestry systems in the carbon budget has been underestimated because of many uncertainties in the drivers affecting carbon dynamics in these highly variable spatial and seasonal biomes.

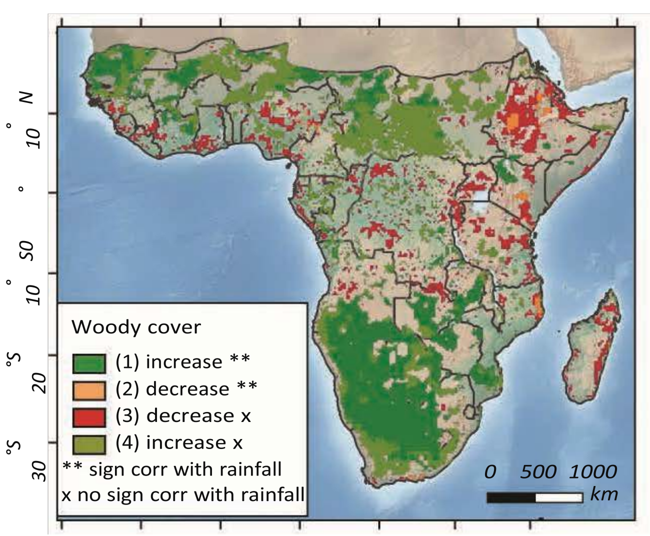

Fig. 3. Apparent changes in woody cover in Africa, related to rainfall and land use. Source: Mbow et al. 2020.

4.0 Increasing TOF Influence on Carbon Sequestration and Storage.

The strong positive and persistent long-term changes in tree cover observed from ground and space-borne measurements have a clear and favorable influence on the global carbon budget. For example, the contribution of the Sahel to global terrestrial carbon uptake has reversed from source to sink since 1981 (Mbow et al. 2020) (**Fig. 4**). The high carbon sequestration potential for TOF systems such as agroforestry, coupled to the co-benefits to increased food security and animal production, is well established (Smith et al., 2014; Carsan et al., 2014). In terms of sequestration per unit of land, TOF-Agroforestry lags behind only natural-forest restoration. As a mitigation intervention, it is seven times more effective than most timber tree plantations in the tropics, especially in semi-arid regions (Lewis et al., 2019) and it reinforces several adaptation objectives, such as food and nutrition, livestock productivity, and soil fertility. The role of semiarid agroforestry systems in the carbon budget has been underestimated because of many uncertainties in the drivers affecting carbon dynamics in these highly variable spatial and seasonal biomes.

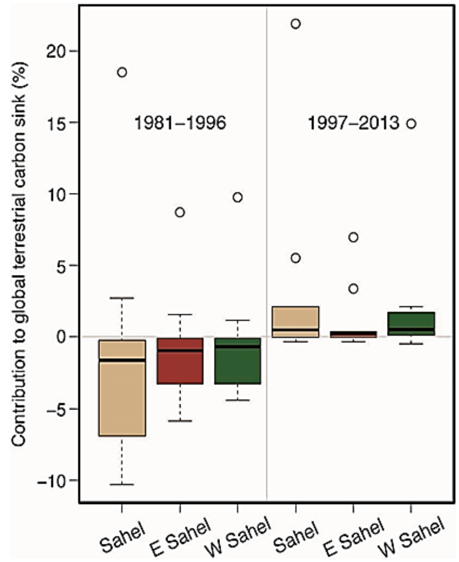

Fig. 4. West African carbon sink. Source: Mbow et al. 2020.