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Does REDD+ have a chance? Implications from Pemba, Tanzania

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Abstract Conservation scientists continue to debate the strengths and weaknesses of REDD+ as an instrument to slow greenhouse gas emissions in the developing world. We propose that general positions on this debate are less helpful than drawing lessons from specific investigations into the features of individual projects that make them successful or not. Here, focusing on a site-specific REDD+ intervention in Pemba, Zanzibar (Tanzania), we examine the circumstances under which REDD+ has a chance of success, teasing out specific features of both REDD+ interventions and the socio-economic and institutional contexts that render REDD+ a potentially valuable complement to community forestry. Additionally, we highlight some unanticipated positive outcomes associated with the design features of REDD+ projects. Our broader goal is to move away from ideologically-driven debate to empirically-based identification of general conditions where REDD+ could work, and to provide policy recommendations.

Keywords Carbon payments, community forestry, Pemba, REDD+, Tanzania, Zanzibar

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Introduction

REDD+ (Reducing Emissions from Deforestation and forest Degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries) was adopted by the Conference of Parties to the United Nations Framework Convention on Climate Change in 2007 as a strategy to slow forest loss and as a mechanism for sustainable development. Since then REDD+ has become the largest anti-deforestation initiative in history (Angelsen, 2017), drawing on a complex set of multilateral, bilateral, private, corporate, foundation and domestic investment sources (Environmental Defence Fund, 2018). More than 50 countries have initiated REDD+ programmes, and there are now > 350 projects across the tropics (Duchelle et al., 2018). Most, however, have no access to the anticipated performance-based finance from voluntary carbon markets (as defined by Seymour & Busch, 2016, see also Simonet et al., 2014; Sunderlin et al., 2015; Angelsen, 2016), but rely instead on results-based multilateral or bilateral aid (Duchelle et al., 2018). Prompted in part by this uneven process in establishing successful REDD+ programmes, a divisive literature has emerged. Some see REDD+ as simultaneously positive for carbon, biodiversity and poverty alleviation (e.g. Angelsen, 2008), citing proven results (Jayachandran et al., 2017) and its potential to garner public and private finance (e.g. Seymour & Busch, 2016). Others are concerned with the dangers to local community well-being inherent in commodification and monopolization of natural resources (Phelps et al., 2010; Sandbrook et al., 2010), particularly in contexts with poor governance structures where vulnerable populations are at risk of displacement by multinational corporate interests (for an example, see McDermott, 2017). For this reason most now agree that monitoring of non-carbon outcomes (co-benefits such as livelihoods, tenure security, equitable benefit sharing and biodiversity; Hinsley et al., 2015) is critical.

Much of this debate stems from viewing REDD+ as a monolithic, singular entity. In reality, programmes represent a wide variety of institutional forms, some of which function better than others, and vary with respect to their fit to the institutional and socio-economic context. Systematic comparisons of REDD+'s empirical successes and failures are thwarted by the highly diverse nature and structure of

REDD+ projects, and their scale, community involvement, certification standards and dependence on market-based mechanisms (Simonet et al., 2014). Put another way, the degree to which site-specific design features align with broader economic/social/cultural institutions, such as free markets, rule of law and public opinion will determine the success and appropriateness of different REDD+ designs.

Consequently, debates regarding whether it is worth persisting with REDD+ as a global strategy, and in what form, should shift towards determining the specific contexts in which the instrument could be effective. We advocate such a transition because general debates concerning neo-liberalism and environmental commodification, although important, do not provide definitive guidance for immediate global challenges.

To this end we (a collaboration of partners involved with REDD+ either directly as government and non-governmental implementing agencies, or indirectly as academics) review the situation surrounding a REDD+ project in Zanzibar, Tanzania. We identify and discuss salient features of the project as implemented on the island of Pemba that, to the extent to which they are generalizable, demonstrate how, and under what specific conditions, REDD+ could be a valuable mechanism for reducing greenhouse gas emissions. In particular, we draw attention to the source of the threats (corporate and/or community), the importance of pre-existing management institutions, often overlooked complementarities between centralized and decentralized management, and counterintuitive consequences of leakage.

REDD+ in Zanzibar

In 2009 Tanzania was identified as an appropriate country for piloting REDD+ because of its extensive dry tropical forest cover and rapid rates of deforestation. With the principal support of the Norwegian government, Tanzania established eight site-specific REDD+ pilot projects, for which USD 93 million was pledged (Burgess et al., 2010). These initiatives aimed to revitalize a history of local community-based forest management, to secure land rights, to invest in local capacity for measurement, reporting and verification, and to engage the private sector (Burgess et al., 2010; Katani et al., 2016; Lund et al., 2017).

One of these projects is Zanzibar's Hifadhi ya Misitu ya Asili programme, implemented under CARE International. Zanzibar consists of two main islands (Unguja and Pemba, the latter known as the Green Isle; Supplementary Material 1). Pemba and Unguja are characterized by a mix of mangrove forest (7% on both islands combined but 13% on Pemba), coral rag forest (37% and 12%), high forest (4% and 2%), and agroforestry (32% and 44%) (Revolutionary Government of Zanzibar, 2008; Terra Global Capital, 2014). As a result of a long history of agroforestry, the original native forest is limited; the remainder contains a mixture of native forest with agroforestry species (introduced fruit, nut and spice trees). The annual rate of deforestation across both islands is 1.1% (Revolutionary Government of Zanzibar, 2014), driven primarily by population pressure (growing at 3.2% per annum; Siex, 2011) and poverty (on Pemba 90% of the population relies exclusively on charcoal and firewood for cooking). Fuelwood and charcoal account for 37% of the drivers of deforestation, shifting cultivation and fuelwood lots for a further 26%, and timber (for house and boat construction) for 5%; activities are conducted primarily by local community members, less so by local entrepreneurs (Terra Global Capital, 2014). Thus, deforestation on Pemba is primarily a function of household rather than business or government interests, unlike many other threatened forests globally (Hosonuma et al., 2012). Only 14% of all biomass consumption is accounted for by institutions and business (which are primarily local bakeries; Terra Global Capital, 2014). Rates of deforestation are expected to increase with population growth, renewed pressure for clove production (as global prices increase), and illegal offtake associated with construction for a burgeoning tourist sector on the southern island (Unguja) and government/military installations in the archipelago (Revolutionary Government of Zanzibar, 2008).

The Hifadhi ya Misitu ya Asili programme was designed to slow deforestation through poverty reduction, and to reduce greenhouse gas emissions through developing and strengthening the capacity of communities to manage existing forests (Caplow et al., 2014). It involved a collaboration between a local facilitating umbrella NGO (Jumuiya ya Uhifadhi wa Misitu ya Jamii Zanzibar), CARE International, the government's Department of Forestry and Non-Renewable Natural Resources, and a San Francisco-based technical advisor (Terra Global Capital). The principal activities conducted by Hifadhi ya Misitu ya Asili entailed: (1) facilitating registration of Community Forest Management Agreements at the shehia (ward) level (thereby securing land tenure), (2) zoning high protection forested areas within each shehia, (3) supporting Shehia Conservation Committees through education, planting, restoration and the patrol and fining of illegal forest harvesting, and (4) administering trial motivation payments on the basis of shehia performance. Eighteen shehia were invited by CARE, in conjunction with the Department of Forestry, to participate in the programme. Selection criteria included a high per cent of forest cover, rapid rates of deforestation (a mean of 3.3% per annum during 2001–2010 for the 18 shehia initially selected), and free and informed consent. In August 2015 all 18 shehia had their Community Forest Management Agreements formally registered (Plate 1). At this point CARE International withdrew, and the project ended (Royal Norwegian Embassy, 2015), although the application for validation and verification of carbon issuance had not yet cleared the auditing process, a delay resulting

PLATE 1 The celebration for the 18 shehia with registered Community Forest Management Agreements at the close of the Hifadhi ya Misitu ya Asili programme project, attended by the President of the Revolutionary Government of Zanzibar and representatives from the Royal Norwegian Embassy and CARE International (Pemba, August 2015; photo: M. Borgerhoff Mulder).

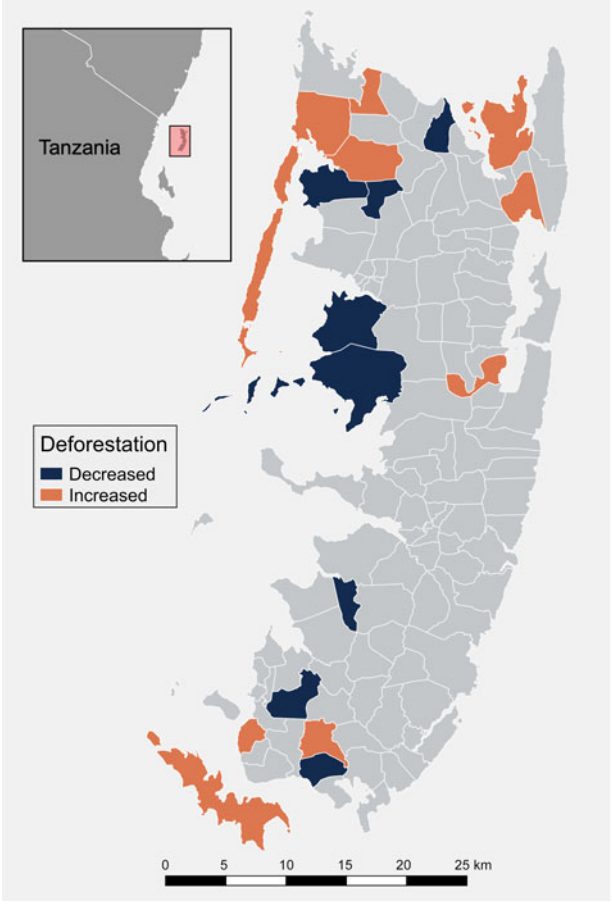

FIG. 1 Pemba, showing the 18 shehia with Community Forest Management, and the annual rate of deforestation in each (from Landsat 5, 7 and 8 imagery) between our historical base (2001–2010) and 2010–2018. Deforestation has decelerated (or reversed) in eight shehia and accelerated in 10 shehia. All details, including source of shape files, are in Supplementary Material 2.

primarily from high transaction costs associated with the technical complexities of constructing cloud-free satellite images as a forest cover baseline.

Sunderlin et al. (2015) deemed Zanzibar's Hifadhi ya Misitu ya Asili programme defunct but this was premature (see also Blomley et al., 2017). On the one hand, 18 Pemban shehia have formally recognized registered Community Forest Management Agreements, although one is currently ceding its status. Another 10 shehia have elected to enter the process, four await final ministerial signature, and six are in the registration process. On the other hand, there are as yet no carbon payments to communities for their conservation efforts because of continued delay in validation and verification. Despite these problems, most communities are still conducting conservation activities and, with no operational budget, Department of Forestry staff continue to work with them, assisting the Shehia Conservation Committees with management issues, for example.

To date, the outcomes for Pemban communities with Community Forest Management Agreements status are mixed. On the positive side, with their registration titles, shehia have stronger tenure rights to their forests, authority to charge revenue for legal timber use, and clearly defined land-use plans. There are some indications of success, albeit limited. A comparison of baseline rates of deforestation (2001–2010) to recent rates (2010–2018) reveals that of the 18 Pemban shehia with registered Community Forest Management Agreements six have managed to slow their rates of net deforestation during 2010–2018 (Fig. 1, Supplementary Material 2, Supplementary Tables 1 & 2), and two had greater forest cover in 2018 than in 2010. Community members point to the help they receive from the Department of Forestry in managing their forests, particularly with respect to the fining of those who steal trees and the removal of corrupt Shehia Conservation Committee members (JA & ASN, unpubl. data). REDD-ready communities have also benefitted from motivation payments that were distributed either as community benefits (health facilities, mosques, madrassa) or as household payments. Furthermore, many shehia now have small-scale enterprise groups who plant firewood lots and sell their produce. Finally, there are now shehia petitioning the Department of Forestry to enter the REDD+ process (the 10 cases mentioned above, and see further details below).

On the negative side, deforestation persists in all but two shehia, and the rate is increasing in 10 shehia (Fig. 1). Although this is perhaps unsurprising given the absence of any financial support since 2014 and of any carbon payments, this indicates that the conservation behaviour promoted by REDD-readiness has not percolated to the majority of shehia that participated in Hifadhi ya Misitu ya Asili. Most palpably, the 'economy of expectations' (Fletcher et al., 2016) looms large. For almost 5 years

TABLE 1 The fate of REDD+ pilot projects in Tanzania. These data are for REDD+ pilot projects supported by the Norwegian Embassy[1].

Location	Communities issued carbon credits	Communities selling carbon credits
Lindi	Yes[2]	No[2]
Kilwa	No	No[2]
Zanzibar	No	No[2]
Kilosa	No	No[2]
Kondoa	No	No
Kigoma	No	No
Shinyanga	No	No
Rungwe	No	No[2]

[1]An additional REDD+ project, in Yaeda Valley, is selling carbon credits as of 2019 but was not part of the original Norwegian project.
[2]Data from personal communication to JBA from May 2017 onwards (also see Simonet et al., 2014), updated using online databases as of March 2019.

communities have been motivated with the promise of carbon payments, yet nothing has materialized and there is marked frustration. Internal conflicts emerge when land zoned for high protection contains clove trees; families now plan to revive clove production, to capitalize on improved market prices. Community members also feel that the government and/or project is failing to provide them with the anticipated financial assistance. Finally, there is a technical disagreement over the calculation of the value of Zanzibar's terrestrial carbon (Ravikumar et al., 2017; Supplementary Material 1). In short, outcomes are mixed. There is only weak evidence of slowing deforestation in some shehia, reductions that cannot be directly linked to the Hifadhi ya Misitu ya Asili programme; furthermore, although the programme yields important co-benefits these cannot substitute for increased carbon storage.

To some extent the experiences of Hifadhi ya Misitu ya Asili mirror those from other Tanzanian REDD+ sites (Table 1), and the broader global situation (Sunderlin et al., 2015; Seymour & Busch, 2016). Most notably none of the Norwegian initiative projects appear to have yet generated carbon payments. The measurement, reporting and verification required for carbon certification demands technical expertise that community-based projects struggle to access (Phelps et al., 2010), leading to long delays, no payments and faltering communication. More specifically, some studies reveal internal conflicts over land zoning as a common occurrence (Larson et al., 2013; Dokken et al., 2014), often exacerbated by corruption and elite capture, as in Unguja (Benjaminsen, 2014; but see Sutta & Silayo, 2014) and elsewhere (e.g. Scheba & Rakotonarivo, 2016), as well as failure to reach desired levels of participation (Eilola et al., 2015). Although there are reports of successful community engagement in some cases (e.g. Uisso et al., 2019), elsewhere disenfranchisement is emphasized (Bartholdson et al., 2019). More generally, REDD+ projects exist within a complicated web of NGOs, consultants, government agencies, businesses and international bodies. From the perspective of communities living at the forest edge, and the local organizations that act on their behalf, navigating these networks demands daunting levels of human and social capital.

Recommendations for where REDD+ could work

Not all drivers of deforestation are the same

Perhaps the most trenchant critique of REDD+ is that it is unable to counter political and economic interests that stand to gain from the conversion of tropical forests. Examples of these business as usual scenarios are the soy industry in Brazil and oil palm industry in Indonesia, where REDD+ is effectively outbid by commercial profit-seekers. Links between commercial logging companies and government ministers, or between agricultural subsidies and corruption, are a persistent global challenge (e.g. Sills et al., 2014; Capitani et al., 2019).

Nonetheless, situations differ by context. On Pemba the primary drivers of deforestation are local: households extracting fuel and timber, and their expanding agricultural/clove production. Communities also have interests in the fruits and medicines available in the forest, and children hunt forest birds and mammals. Although there is some illegal offtake by government and commercial interests, this is not a significant driver of deforestation in comparison to uses by local communities (Terra Global Capital, 2014; Blomley et al., 2016).

Even the revival of the historically important clove industry (Sheriff, 1987) on Pemba differs structurally from that of large scale business as usual operations. After a slump in the 1990s, clove prices are currently rebounding towards a historical high (Brzoskiewicz, 2018). Although cloves are grown in agroforestry plots and agroforestry is a major source of loss of native forest, there are three factors that mitigate this to some extent. Firstly, cloves are locally-owned, albeit sometimes by affluent families with roots in Oman (reflecting the flight of the wealthiest land-owning class to that country after the 1964 revolution); nevertheless, both local and Oman-based clove-owning families have strong kin ties on the island, and are not equivalent to foreign corporate interests. Secondly, cloves are not grown in conventional plantations, but in an agroforestry matrix. As such, cloves do not pose a landscape-level threat comparable to oil palm or soy mono-cropping. Thirdly, because forests interspersed with clove trees contribute to land considered forested by verification standards (because the woody biomass still holds carbon), there is little opportunity cost for communities attempting to maximize carbon storage as they can benefit simultaneously from cloves and carbon.

In short, Pemba is not a case where REDD+ is challenged by conventional plantation economies or land grabs.

Accordingly we contend that valid critiques of REDD+ as a strategy in Brazil and Indonesia (Brockhaus et al., 2012; Edwards et al., 2012; Henders et al., 2015) are misplaced for a large number of REDD+ projects where forest-dependent communities are struggling to make a living; these communities have interests in protecting their forests from outsiders. In this sense our conclusions align with those of Robinson et al. (2013) for other sites in Tanzania, where key drivers of deforestation are also local extraction of forest products (see also Blomley et al., 2016). In such contexts an approach based on community forestry linked to REDD+ can offer a suite of incentives to reduce deforestation, precisely because its incentives reward those primarily responsible for deforestation.

Centralization is not inevitable

Since its inception, the risk of centralization has loomed over REDD+ (Phelps et al., 2010; Sandbrook et al., 2010). The main concerns are loss of community control over traditional forests (Barr & Sayer, 2012), exclusionary government regulations (Thompson et al., 2011), and elite capture (Andersson et al., 2018). Where these occur, centralized forest management engendered by REDD+ can undercut community management (Brown, 2013). Centralizing tendencies emerge in part because REDD+ is increasingly implemented at a national or jurisdictional level (ostensibly to avoid leakage), and in part because complex carbon accounting, including monitoring, reporting and verification, demands expertise from skilled partners who are generally unavailable locally (Phelps et al., 2010). In addition, the increased commodity value of forests on environmental markets inevitably lures central governments, and/or other investors, to seek rents or land grabs (Sandbrook et al., 2010). Nevertheless, REDD+ projects vary greatly in their scale, degree of centralization and how each programme interacts with government institutions (West, 2016), making such generalizations problematic.

Tanzania has a history of progressive forest management that provides fortuitous institutional pre-adaptations for the development of REDD+ institutions (Burgess et al., 2010; Kweka et al., 2015; Blomley et al., 2016). The Hifadhi ya Misitu ya Asili programme grew out of this tradition, specifically from an earlier (1996–2005) small community forestry project funded by CARE, which focused on conservation and community development in 10 villages around Ngezi forest, the largest remaining area of high forest on the island. Because of these early successes, the Hifadhi ya Misitu ya Asili partners elected to scale up this community management model from the village to the shehia level, and roll it out at the archipelago scale. Thus, the programme was not imposed on a void but rather built onto a history of decentralized forest management with formal government support; conservation committees, albeit of varying skills, reputation and credibility, already existed at some sites. Some such committees date back to British colonial conservation policies (Supplementary Material 3) and continue to display strong commitments to protecting their forests. Engaging with existing institutions rather than imposing new structures is associated with successful outcomes for community projects (Brooks et al., 2012). In short, with such pre-existing institutions pressures for centralization are less likely to destroy REDD+ programmes.

Quite to the contrary, across Pemba we observe considerable opportunities for complementarities between community management and government oversight. Not only does the fate of government-run forests depend heavily on the activities of Shehia Conservation Committees in neighbouring communities, but members of the Shehia Conservation Committees depend on Department of Forestry personnel to help depersonalize socially costly punishments and fines amongst otherwise tightly-knit communities (Robinson & Lokina, 2012). There is thus a synergy in which both communities and the forest department provision specialized conservation goods that they each have an advantage in producing. This may be a byproduct of an unusually highly community-orientated stance amongst some government personnel (Eilola et al., 2015), but it shows that REDD+ interventions can potentially profit from closer coordination (either spatially or institutionally) with government institutions when there are benefits from specialization.

Leakage can promote conservation adoption

Finally, we note that leakage, typically considered a barrier to sub-national programmes, can be co-opted under specific conditions to drive the spread of community forestry. Leakage is a major problem for any performance-based payments intervention scheme because people and communities can simply shift their environmentally degrading activities to other areas (Atmadja & Verchot, 2012). As elsewhere, leakage occurs on Pemba. Once a REDD+ shehia begins to develop formal institutions to protect its local forest, citizens are potentially incentivized to enter neighboring shehia that do not have such protections, to harvest forest products. This is particularly prevalent given the mosaic structure of the REDD+ shehia (Fig. 1). The result is a growth in the rate of deforestation for adjoining shehia and an increase in competition amongst communities over remaining patches of forest. To reduce leakage, multiple adjoining shehia have begun to petition the Department of Forestry to obtain Community Forest Management Agreements, thereby attaining the legal rights to develop their own institutions to protect their forests from outsiders (Andrews & Borgerhoff Mulder, 2018); this mirrors instances of shehia cooperation seen in Unguja (Eilola et al., 2015). Capitalizing on the shift in opportunity costs created by leakage into adjoining areas allows REDD+ projects to leverage this 'frontier effect' (cf. Turchin, 2003) to promote a cascade

of interest amongst non-participating communities. This means that in places already suffering high offtake from external sources, local people are likely to have high demand for the services that conservation programmes such as REDD+ can offer. Such interest is of course critical to the provision of free and prior informed consent, integral to acquiring Community Forest Management Agreement status.

Conclusion

We propose that generalizations about REDD+ are counterproductive. Instead, and by way of recommendations regarding implementation, we advocate identifying economic, ecological and institutional settings in which REDD+ may be able to deliver its promises. As a team working on Pemba, we believe that many of the currently popular critiques of REDD+ focus on conditions that are not generalizable. Firstly, the threat to community management does not always lie in countering multinational corporate interests in forests: forest-dependent communities can share some goals with advocates of REDD+ with respect to excluding outsiders. Secondly, REDD+ initiatives, when built onto pre-existing decentralized, community-based forestry institutions, will not inevitably fall prey to the predatory whims of centralized government: there are overlooked complementarities between centralized top-down governance and local community management, with each specializing in producing different institutional goods. Finally, there may be unanticipated benefits from the occurrence of leakage that can be harnessed to expand site-specific REDD+ interventions.

We do not downplay the challenges facing incipient REDD+ projects, nor suggest that conditional payments are a panacea for success or that REDD+ in Pemba is, or will ever be, a success. But we do contend that dismissals of REDD+ as a doomed conservation fad fail to appreciate the diversity of programmes and actors, and the great amount of institutional learning that has taken place in this process.

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Conflicts of interest Jumuiya ya Uhifadhi wa Misitu ya Jamii Zanzibar is the implementing NGO, but all authors are motivated to improve the chances of REDD+ being implemented on Zanzibar for the reasons argued herein.

Ethical standards This research was conducted with permission of the Revolutionary Government of Zanzibar. Ethical clearance was granted by University of California Davis Institutional Review Board ID991486 to MBM for 'Community-Based Forest Conservation under REDD in Pemba, Zanzibar', and the research otherwise abided by the *Oryx* guidelines on ethical standards.

References

Andersson, K.P., Smith, S.M., Alston, L.J., Duchelle, A.E., Mwangi, E., Larson, A.M. et al. (2018) Wealth and the distribution of benefits from tropical forests: implications for REDD+. *Land Use Policy*, 72, 510–522.

Andrews, J. & Borgerhoff Mulder, M. (2018) Cultural group selection and the design of REDD+: insights from Pemba. *Sustainability Science*, 13, 93–107.

Angelsen, A. (2008) *Moving Ahead with REDD: Issues, Options and Implications*. CIFOR, Borgor, Indonesia.

Angelsen, A. (2017) REDD+ as result-based aid: general lessons and bilateral agreements of Norway. *Review of Development Economics*, 21, 2371–264.

Atmadja, S. & Verchot, L. (2012) A review of the state of research, policies and strategies in addressing leakage from reducing emissions from deforestation and forest degradation (REDD+). *Mitigation and Adaptation Strategies for Global Change*, 17, 311–336.

Barr, C.M. & Sayer, J.A. (2012) The political economy of reforestation and forest restoration in Asia–Pacific: critical issues for REDD+. *Biological Conservation*, 154, 9–19.

Bartholdson, O., Abdallah, J.M., Marquardt, K. & Salomonsson, L. (2019) Is REDD+ more of an institutional affair than a market process? The concealed social and cultural consequences of an ongoing REDD+ project in Kolo Hills, Tanzania. *Forests*, 10, 618.

Benjaminsen, G. (2014) Between resistance and consent: project—village relationships when introducing REDD+ in Zanzibar. *Forum for Development Studies*, 41, 377–398.

Blomley, T., Edwards, K., Kingazi, S., Lukumbuzya, K., Mäkelä, M. & Vesa, L. (2016) *REDD+ Hits the Ground: Lessons Learned From Tanzania's REDD+ Pilot Projects*. IIED, London, UK.

Blomley, T., Edwards, K., Kingazi, S., Lukumbuzya, K., Mäkelä, M. & Vesa, L. (2017) When community forestry meets REDD+: has REDD+ helped address implementation barriers to participatory forest management in Tanzania? *Journal of Eastern African Studies*, 11, 549–570.

Brockhaus, M., Obidzinski, K., Dermawan, A., Laumonier, Y. & Luttrell, C. (2012) An overview of forest and land allocation policies in Indonesia: is the current framework sufficient to meet the needs of REDD+? *Forest Policy and Economics*, 18, 30–37.

Brooks, J.S., Waylen, K.A. & Borgerhoff Mulder, M. (2012) How national context, project design, and local community characteristics influence success in community-based conservation projects. *Proceedings of the National Academy of Sciences of the United States of America*, 109, 21265–21270.

Brown, I.M. (2013) *Redeeming REDD: Policies, Incentives and Social Feasibility*. Earthscan, Oxford, UK.

Brzoskiewicz, R. (2018) *Tanzania Spice Industry Outlook to 2018—Driven by Local Association Endeavors and Organic Farming*. satprnews.com/2018/01/24/tanzania-spice-industry-outlook-to-2018-driven-by-local-association-endeavors-and-organic-farming [accessed 23 February 2018].

Burgess, N.D., Bahane, B., Clairs, T., Danielsen, F., Dalsgaard, S., Funder, M. et al. (2010) Getting ready for REDD+ in Tanzania: a case study of progress and challenges. *Oryx*, 44, 339–351.

Capitani, C., van Soesbergen, A., Mukama, K., Malugu, I., Mbilinyi, B., Chamuya, N. et al. (2019) Scenarios of land use and land cover change and their multiple impacts on natural capital in Tanzania. *Environmental Conservation*, 46, 17–24.

Caplow, S., Putri, A.A.D. & Kweka, D.L. (2014) Piloting REDD in Zanzibar through community forest management, Tanzania. In *REDD+ on the Ground* (ed. E.O. Sills), pp. 234–244. CIFOR, Bogor, Indonesia.

Dokken, T., Caplow, S., Angelsen, A. & Sunderlin, W.D. (2014) Tenure issues in REDD+ pilot project sites in Tanzania. *Forests*, 5, 234–255.

Duchelle, A.E., Simonet, G., Sunderlin, W.D. & Wunder, S. (2018) What is REDD+ achieving on the ground? *Current Opinion in Environmental Sustainability*, 32, 134–140.

Edwards, D.P., Koh, L.P. & Laurance, W.F. (2012) Indonesia's REDD+ pact: saving imperilled forests or business as usual? *Biological Conservation*, 151, 41–44.

Eilola, S., Fagerholm, N., Mäki, S., Khamis, M. & Käyhkö, N. (2015) Realization of participation and spatiality in participatory forest management—a policy–practice analysis from Zanzibar, Tanzania. *Journal of Environmental Planning*, 58, 1242–1269.

Environmental Defence Fund (2018) *Mapping Forest Finance: a Landscape of Available Sources of Finance for REDD+ and Climate Action in Forests*. edf.org/sites/default/files/documents/EDF101-REDD%2BFinance.pdf [accessed 3 February 2020].

Fletcher, R., Dressler, W., Buscher, B. & Anderson, Z.R. (2016) Questioning REDD+ and the future of market-based conservation. *Conservation Biology*, 30, 673–675.

Henders, S., Persson, U.M. & Kastner, T. (2015) Trading forests: land-use change and carbon emissions embodied in production and exports of forest-risk commodities. *Environmental Research Letters*, 10, 125012.

Hinsley, A., Entwistle, A. & Pio, D.V. (2015) Does the long-term success of REDD+ also depend on biodiversity? *Oryx*, 49, 216–221.

Hosonuma, N., Herold, M., de Sy, V., de Fries, R., Brockhaus, M., Verchot, L. et al. (2012) An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters*, 7, 1–12.

Jayachandran, S., de Laat, J., Lambin, E.F., Stanton, C.Y., Audy, R. & Thomas, N.E. (2017) Cash for carbon: a randomized trial of payments for ecosystem services to reduce deforestation. *Science*, 357, 267–273.

Katani, J.Z., Mustalahti, I., Mukama, K. & Zahabu, E. (2016) Participatory forest carbon assessment in south-eastern Tanzania: experiences, costs and implications for REDD+ initiatives. *Oryx*, 50, 523–532.

Kweka, D., Carmenta, R., Hyle, M., Mustalahti, I., Dokken, T. & Brockhaus, M. (2015) *The Context of REDD+ in Tanzania: Driver, Agents and Institutions*. Occasional Paper no. 133. Center for International Forestry Research, Bogor, Indonesia.

Larson, A.M., Brockhaus, M., Sunderlin, W.D., Duchelle, A., Babon, A., Dokken, T. et al. (2013) Land tenure and REDD+: the good, the bad and the ugly. *Global Environmental Change*, 23, 678–689.

Lund, J.F., Sungusia, E., Mabele, M.B. & Scheba, A. (2017) Promising change, delivering continuity: REDD+ as conservation fad. *World Development*, 89, 124–139.

McDermott, C.L. (2017) Whose forests, whose gain? *Nature Climate Change*, 7, 386.

Phelps, J., Webb, E.L. & Agrawal, A. (2010) Does REDD+ threaten to recentralize forest governance? *Science*, 328, 312–313.

Ravikumar, A., Larjavaara, M., Larson, A. & Kanninen, M. (2017) Can conservation funding be left to carbon finance? Evidence from participatory future land use scenarios in Peru, Indonesia, Tanzania, and Mexico. *Environmental Research Letters*, 12, 014015.

Revolutionary Government of Zanzibar (2008) *Zanzibar National Forest Resources Management Plan (2008–2020)*. The Revolutionary Government of Zanzibar, Zanzibar.

Revolutionary Government of Zanzibar (2014) *Zanzibar's Climate Change Strategy*. The Revolutionary Government of Zanzibar, Zanzibar.

Robinson, E.J. & Lokina, R.B. (2012) Efficiency, enforcement and revenue tradeoffs in participatory forest management: an example from Tanzania. *Environment and Development Economics*, 17, 1–20.

Robinson, E.J., Albers, H.J., Meshack, C. & Lokina, R.B. (2013) Implementing REDD through community-based forest management: lessons from Tanzania. *Natural Resources Forum*, 37, 141–152.

Royal Norwegian Embassy (2015) *Final Review of the Project. Piloting REDD+ in Zanzibar through Community Forest Management, June 2015*. NIRAS, Vantaa, Finland.

Sandbrook, C., Nelson, F., Adams, W.M. & Agrawal, A. (2010) Carbon, forests and the REDD paradox. *Oryx*, 44, 330–334.

Scheba, A. & Rakotonarivo, O.S. (2016) Territorialising REDD+: conflicts over market-based forest conservation in Lindi, Tanzania. *Land Use Policy*, 57, 625–637.

Seymour, F. & Busch, J. (2016) *Why Forests? Why Now? The Science, Economics, and Politics of Tropical Forests and Climate Change*. Brookings Institution Press, Center for Global Development, Washington, DC, USA.

Sheriff, A. (1987) *Slaves, Spices and Ivory in Zanzibar: Integration of an East African Commercial Empire Into the World Economy, 1770–1873*. Ohio University Press, Athens, USA.

Siex, K. S. (2011) *Protected Area Spatial Planning for Unguja and Pemba Islands, Zanzibar*. Wildlife Conservation Society, Zanzibar, Tanzania.

Sills, E.O., Stibniati, S.A., De Sassi, C., Duchelle, A.E., Kweka, D.L., Pradnja, I.A.R. & Sunderlin, W.D. (eds) (2014) *REDD+ on the Ground: A Case Book of Subnational Initiatives Across the Globe*. Center for International Forestry Research, Bogor Barat, Indonesia.

Simonet, G., Karsenty, A., de Perthuis, C., Newton, P. & Schaap, B. (2014) *REDD+ Projects in 2014: An Overview Based on a New Database and Typology*. Information and Debate Series No 32. Paris-Dauphine University, Paris, France.

Sunderlin, W.D., Sills, E.O., Duchelle, A.E., Ekaputri, A.D., Kweka, D., Toniolo, A. et al. (2015) REDD+ at a critical juncture: assessing the limits of polycentric governance for achieving climate change mitigation. *International Forestry Review*, 17, 400–413.

Sutta, H. E. & Silayo, D.A. (2014) REDD+ Piloting process in the Zanzibar Islands, Tanzania: the assessment of the community's perceptions and attitudes. *Ethiopian Journal of Environmental Studies and Management*, 7, 548–560.

Terra Global Capital (2014) *HIMA (Hifadhi ya Misitu ya Asili ya jamii) REDD+ Program PD v-0-19 DRAFT*. vcsprojectdatabase.org/#/pipeline_details/PL1381 [accessed 27 March 2018].

Thompson, M.C., Baruah, M. & Carr, E.R. (2011) Seeing REDD+ as a project of environmental governance. *Environmental Science & Policy*, 14, 100–110.

Turchin, P. (2003) *Historical Dynamics: Why States Rise and Fall*. Princeton University Press, Princeton, USA.

Uisso, A.J., Chirwa, P.W., Ackerman, P.A. & Mbwambo, L. (2019) Forest management and conservation before and after the introduction of village participatory land use plans in the Kilosa district REDD+ initiative, Tanzania. *Journal of Sustainable Forestry*, 38, 97–115.

West, T.A. (2016) Indigenous community benefits from a de-centralized approach to REDD+ in Brazil. *Climate Policy*, 16, 924–939.

Does REDD+ have a chance? Implications from Pemba Tanzania

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SUPPLEMENTARY MATERIAL 1 HIMA: Funding period and debates over carbon density.

The project "Hifadhi ya Misitu ya Asili (HIMA) – Piloting REDD+ in Zanzibar through Community Forest Management" was designed and implemented between April 2010 and December 2014 by CARE International, the Department of Forestry and Non-Renewable Natural Resources (DFNRNR), the US-based company Terra Global, and the local community forestry NGO (JUMIJAZA). It received a no-cost extension until August 2015.

Here we respond to a recent claim that Zanzibar's forests have a comparatively low carbon density value (Ravikumar et al. 2017), thereby rendering Zanzibar a poor model from which to generate insights for REDD+ more generally. We contest this suggestion for two reasons. First, there are conflicting calculations about the precise carbon density of Zanzibar, resulting from the fact that multiple Woody Biomass Surveys exist that use different methodologies for counting trees and calculating carbon density. Updated calculations are currently being performed by Terra Global Capital, which will become the official statistics used for the REDD+ project. Second, the presumption that low-density projects will fail due to their low supply of carbon credits neglects market dynamics. The market price of carbon credits varies across projects in accordance with the various attributes that include poverty reduction, preservation of biodiversity, the extent to which the project assures "no harm" and "permanence", as well as perhaps its international recognition. Therefore, by selling high quality credits, projects can partially abate the problem of a low total tonnage through higher prices. Additionally, we would argue that by focusing only on forests with high carbon density, other valuable, unique and threatened forests with lower carbon density, such as some parts of East African coastal forests (Siex, 2011), could become marginalized from conservation.

SUPPLEMENTARY MATERIAL 2 Methods for calculating forest cover change per year per ward

Satellite imagery

In order to quantify forest cover within each ward with a Community Forest Management Agreement (CoFMA, see main paper) and the degree of loss or gain in forest cover over the last two decades, we analysed a collection of Landsat 5, Landsat 7 and Landsat 8 satellite images. Landsat imagery was chosen as it is open source, spans the entire temporal period of the study, and has a high spatial resolution of 30 m^2 and bi-weekly data availability (Cohen & Goward, 2004). A two-year composite image was produced to represent three time periods of interest; 2001 (May 2000–May 2002) and 2010 (October 2009–October 2011) from a combination of Landsat 5 and 7 ETM+, and 2018 (January 2017–January 2019) from Landsat 8 OLI. All images were top-of-atmosphere reflectance, ortho-rectified, and had cloud, water and cloud shadow pixels removed via the mask

CFMASK in Google Earth Engine (GEE) version 7.3.2 (Foga et al., 2017; Gorelick et al., 2017). Each pixel in the resulting composite image represented the median value for visible, NIR and Normalized Difference Vegetation Index (Near Infrared and Red) bands computed from the input imagery.

Training data

Eight land cover classifications were initially identified in Pemba; mangrove forest, natural high forest, agriculture, urban development, bare land, coral rag shrub, coral rag forest and agroforestry. We collected > 400 waypoints via a handheld GPS device (Garmin eTrex 20 GPS handheld unit) within a subset of wards on the island during a field survey in June–July 2015 and inspected the waypoints on Google Earth imagery for 2015. To obtain training points across the entire island, we then created training data locations by purposefully selecting 440 coordinates throughout the island and assigning each coordinate a land cover class via visual inspection from Google Earth 2001, 2010 and 2018 imagery. After preliminary analysis, and in line with the objectives of our study, the number of classifications was reduced to forest (mangrove, coral rag forest and natural high forest) and non-forest (agriculture, urban development, bare land, coral rag shrub, agroforestry).

Land cover classification

Images were classified as forest or non-forest for 2001, 2010 and 2018 using a 'Random Forest' supervised classification in Google Earth Engine. Seventy percent of the training data locations were randomly assigned to train the Landsat 7 and Landsat 8 composite data and the remaining 30 percent used for post-classification accuracy assessment (Hijmans & van Etten, 2012; Stehman, 1997). The resulting classified images' overall accuracy from the confusion matrix was >90% for all images and demonstrated excellent agreement with the kappa coefficient (Supplementary Table 1). Potential sources of error in classifications may be attributed to initial training data collection on Pemba, cloud cover distorting satellite imagery and a Scan Line Corrector error on Landsat 7.

The classified images were clipped to the 18 wards that held a Community Forest Management Agreement (CoFMA) as of 2015. Shapefiles of ward areas were obtained from *Global Administration Areas 3.6* (GADM, 2018). Shapefiles of government forest protected areas were obtained from the National Bureau of Statistics (United Republic of Tanzania). Government forest protected areas that lie within the study region were excluded from spatial analysis. Within each CoFMA, total area (m^2) of forest and non-forest were then quantified for the three years of interest (2001, 2010, 2018) by zonal statistics in *QGIS* (QGIS Development Team, 2018). Due to the number of cloudy pixels differing for each year of imagery, forest area (m^2) was divided by total forest area (m^2) (forest + non-forest) to obtain a percent of the CoFMA that was forest for each year (Supplementary Table 2).

To obtain the change in rate of forest loss or gain before (2001–2010) and after (2010–2018) the implementation of COFMAs, first we calculated the annual rate of forest cover change within all CoFMAs for the two time periods using the Compound Interest Law, as per the Food and Agriculture Organization of the United Nations (FAO, 2016). Secondly, the annual rate of forest cover change pre-treatment (2001–2010) was subtracted from the annual rate of forest cover change

post-treatment (2010–2018; Supplementary Table 2). Calculations were completed within *RStudio 1.1.3* (RStudio Team, 2015).

Classification results

The results of our analysis are shown in Figure 2 and Supplementary Table 2. We emphasize these results do not substitute for the official analysis to be conducted by Terra Global Capital prior to the official audit of the REDD+ project but are based on our best use of Google Earth Engine and Landsat 5, 7 and 8 imagery. The alternative methodology used by Terra Global Capital for calculating forest cover serves a different purpose of determining the total amount of carbon sequestered for the issuance of carbon credits specified in the HIMA project document.

Although the Zanzibar REDD+ project is designed to determine changes in rates of deforestation from a baseline historical rate at the *archipelago* level (Pemba and Unguja, with the exception of urbanized areas) we focus on forested area *per Pemba ward* as the baseline. We do this for two reasons: first, this is the level at which "motivation payments" (see main text) were distributed during the HIMA project and secondly because the CoFMA groups are organized at the ward level.

SUPPLEMENTARY MATERIAL 3 Historical continuity in community forest management: Msitu Mkuu and Ras Kiuyu as examples

As noted in the main text, HIMA was built onto a history of decentralized community forest management in Zanzibar (e.g. Pakenham, 1947) that had formal government support, in some case dating back to British colonial conservation policies (Shao, 1992; Benjaminsen, 2014). We briefly overview the history of two forests on Pemba to illustrate this history of community engagement in forest protection to show the complex complementarities in producing conservation goods.

Msitu Mkuu

Msitu Mkuu (188.5 ha) is a relatively undisturbed area of high coral rag forest and low coral rag thicket located on the North-eastern corner of the Pemba Island (Micheweni District) at the margins between the deep soil and coral rag belt of Ras Kiuyu peninsula. The area was recognized by the British as an area of ecological importance and was closed to woodcutting in 1947, and has since 1964 been jointly managed with the Forestry Department with four communities (Mjini Wingwi, Kilindini, Kwale and Chokaaningayo) as, what is now called, a Forest Reserve. Local measures against illegal cutting have been implemented for many years by people living areas around it.

During a visit to Mjini Wingwi in 2015, the villagers reported memories of a strong British effort to protect the forest. They reported their ancestors' recognition of the importance of the forest, and the assistance they had sought from Mr Parkenham (District Commissioner at the time) for assistance for its protection. The conservation committee also reported a village decision in 1988 to follow up on the mid-century protection strategies, including patrols, with the goal of protecting the forest against threats from local population increase (M. Borgerhoff Mulder, unpublished data, 2015). Villagers and committee members stressed the importance of recognizing the wealth (of an intact

Msitu Mkuu) that their fathers had bequeathed them, as well as the presence of sacred sites in the forest, and traditional medicines. In this respect HIMA did not feel like an imposition.

Ras Kiuyu

Ras Kiuyu forest (Micheweni District) is a particularly interesting case, a high coral rag forest with high biological diversity (Siex, 2011) lying in the ward of Kiuyu Mbuyuni. Heavy deforestation occurred in 1972 during a period of severe drought, and as a result of locally elected elders seeking new lands for agricultural production and forest products. However in 1975 local leaders decided to protect the forest. In 1987 it was reportedly gazetted by DFNRNR as a Forest Reserve with a total area of 270 ha, and in 2013 it was included in the HIMA project under the Coastal Forest Conservation Project. Because it joined the programme late, it lacks the formal recognition granted at the August 2015 ceremony (see main text), and does not therefore appear on our map.

Despite being technically managed by the government as a Forest Reserve in planning (Siex 2011), DFNRNR allows the local community to manage the forest autonomously. This is partly a result of initial intimidation (community members threatening outsiders), and partly through compromise. The government authorities recognize that the strongly independently motivated SCC is protecting the second most intact forest on Pemba by prohibiting incursions of agriculture into the forest, and regulating villagers to twice annual highly restricted harvests (beginning and end of Ramadhan). The committee also fines for illegal timber extraction, allowing exceptions for families in emergency. A cursory visit in 2015 revealed no loss of understory, an indicator of banned firewood collection. The committee also has a vigorous and ancient plantation of trees (referred to as “mikongwe”, ancient trees of very hard wood at which “even a chain saw cries”, which they claim dates back to the 1880s; interview notes M. Borgerhoff Mulder, 2015), but this was not visited. The community has marked the forest boundaries with stone markers.

Kiuyu Mbuyuni community members are adamant the forest is theirs, and not that of DFNRNR. When the government also placed beacons to mark the forest boundaries, community members threw these into the sea, and prevented forestry official visits. Generally, the department has granted effective management to the community and its conservation is proceeding well. There is even, in 2019, discussion of a change in protected status, and joint management with DFNRNR, although nothing yet is finalized

SUPPLEMENTARY TABLE 1 Confusion matrices of the classification map resulting from the Landsat 5 composite image for 2001, Landsat 7 composite for 2010, and Landsat 8 composite for 2018. User and producer accuracy was calculated as per Congalton (1991). Tables show model predictions in columns versus actual classifications in rows.

2001	Non-forest	Forest	Row Total	User Accuracy
Non-forest	86	5	91	94.5%
Forest	3	46	49	93.9%
Column Total	89	51	140	
Producer Accuracy	96.6%	90.2%		
Kappa Coefficient	0.88			

2010	Non-forest	Forest	Row Total	User Accuracy
Non-forest	79	3	82	96.3%
Forest	2	41	43	95.4%
Column Total	81	44	125	
Producer Accuracy	97.5%	93.2%		
Kappa Coefficient	0.91			

2018	Non-forest	Forest	Row Total	User Accuracy
Non-forest	82	0	82	100.0%
Forest	5	38	43	88.4%
Column Total	87	38	125	
Producer Accuracy	94.3%	100.0%		
Kappa Coefficient	0.91			

SUPPLEMENTARY TABLE 2 Total ward-level percent forest cover for the years 2001, 2010 and 2018, and the annual rate of change in forest cover before (2001–2010) and after (2010–2018) HIMA project implementation. Negative annual rates indicate deforestation and positive annual rates indicate reforestation. Wards that demonstrated an improved rate of annual forest cover change in the second time period as compared to the first are marked with a check box in the final column.

Ward	2001 forest cover (%)	2010 forest cover (%)	2018 forest cover (%)	2001–2010 mean annual forest cover change (%/yr)	2010–2018 mean annual forest cover change (%/yr)	Improved annual rate of forest cover change for the second time period: 2010–2018 (Fig. 2)
Changaweni	51.92	31.14	21.43	-5.2	-5.0	✓
Fundo	31.72	22.27	13.44	-3.7	-6.7	
Gando	40.37	33.17	28.92	-2.0	-1.9	✓
Kambini	10.64	9.78	5.93	-0.9	-6.7	
Kangani	24.46	18.23	15.53	-3.0	-2.2	✓
Kifundi	27.27	22.72	17.83	-1.9	-3.3	
Kisiwa Panza	60.89	59.45	47.88	-0.3	-2.9	
Mgelema	57.43	36.52	30.80	-4.7	-2.3	✓
Mgogoni	26.73	11.63	7.12	-8.4	-6.5	✓
Michenzani	23.34	20.34	15.98	-1.4	-3.3	
Mjimbini	30.32	16.37	9.53	-6.3	-7.2	
Mjini Wingwi	26.09	21.42	14.86	-2.1	-4.9	
Msuka Magharibi	7.89	5.27	3.14	-4.2	-6.9	
Mtambwe North	44.07	29.80	29.98	-4.0	0.1	✓
Mtambwe South	55.01	39.34	39.51	-3.5	0.1	✓
Shumba Mjini	52.48	44.60	35.84	-1.7	-3.0	
Tondooni	24.76	20.99	16.08	-1.7	-3.6	
Tumbe Magharibi	18.47	12.64	9.58	-3.9	-3.7	✓

References

BENJAMINSEN, G. (2014) Between resistance and consent: project–village relationships when introducing REDD in Zanzibar. *Forum for Development Studies*, 41**,** 377–398.

COHEN, B. & GOWARD, S.N. (2004) Landsat's role in ecological applications of remote sensing. *BioScience*, 54, 535–545.

CONGALTON, R.G. (1991) A Review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 37, 35–46.

FOGA, S., SCARAMUZZA, P.L., GUO, S., ZHU, Z., DILLEY, R.D., BECKMANN, T. & LAUE, B. (2017) Cloud detection algorithm comparison and validation for operational Landsat data products. *Remote Sensing of Environment*, 194, 379–390.

GADM (DATABASE OF GLOBAL ADMINISTRATIVE AREAS) (2018) *Database of Global Administrative Areas 3.6.* gadm.org [accessed March 2020].

GORELICK, N., HANCHER, M., DIXON, M., ILYUSHCHENKO, S., THAU, D. & MOORE, R. (2017) Google Earth Engine: planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment*, 202, 18–27.

HIJMANS, R.J. & VAN ETTEN, J. (2012) *raster*: Geographic analysis and modeling with raster data. *R* package version 2.0–12. cran.r-project.org/web/packages/raster/index.html [accessed March 2020].

MacDicken, K., Jonsson, Ö., Piña, L., Maulo, S., Contessa, V., Adikari, Y., … D'Annunzio, R. (2016) *Global Forest Resources Assessment 2015: How are the World's Forests Changing?* Food and Agriculture Organisation of the United Nations, Rome, Italy.

PAKENHAM, R.H.W. (1947) *Land Tenure among the Wahadimu at Chwaka, Zanzibar Island*. The Government Printer, Zanzibar Protectorate.

QGIS DEVELOPMENT TEAM (2018) *QGIS Geographic Information System.* Open Source Geospatial Foundation Project. qgis.org/en/site [accessed March 2020].

RSTUDIO TEAM (2015) *RStudio: Integrated Development for R.* RStudio, Inc, Boston, USA. rstudio.com [accessed 30 October 2019].

SHAO, I.F. (1992) The Political Economy of Land Reforms in Zanzibar: Before and After the Revolution. University of Dar es Salaam Press, Dar es Salaam, Tanzania.

SIEX, K.S. (2011) *Protected Area Spatial Planning for Unguja and Pemba Islands, Zanzibar.* Final Consultancy Report submitted to World Wide Fund for Nature (WWF) from Wildlife Conservation Society (WCS), New York, USA.

STEHMAN, S.V. (1997) Selecting and interpreting measures of thematic classification accuracy. *Remote Sensing of Environment*, 62, 77–89.