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A Spanner in the Works: Human–Elephant Conflict Complicates the Food–Water–Energy Nexus in Drylands of Africa

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The two major conservation issues for drylands of Africa are habitat loss or degradation and habitat fragmentation, largely from agriculture, charcoal production, and infrastructural development. A key question for management is how these landscapes can retain their critical ecological functions and services, while simultaneously supporting resilient livelihoods. It is a clear nexus question involving food (agriculture), water, and energy (fuelwood), which is complicated by human–wildlife conflicts. While these could appear disparate issues, they are closely connected in dryland forest landscapes of Africa where elephants occur close to areas of human habitation. For instance, crop failure, whether due to weather or wildlife damage, is a key driver for rural farmers seeking alternative livelihoods and incomes, one of the commonest being charcoal production. Similarly, heavy reliance on wood-based energy often leads to degradation of wildlife habitat, which heightens competition with wildlife for food and water, increasing the possibility of crop-raiding. So, for multifunctional landscapes where elephants occur in close proximity with humans, any food–water–energy nexus activities toward achieving sustainability and resilience should consider human–elephant conflicts (HECs). Here, we broach these food–water–energy nexus issues with a focus on dryland areas of Africa and HECs. We highlight an ongoing study attempting to address this nexus holistically by employing a climate-smart agriculture (CSA) and agro-forestry based design, augmented by an elephant deterrent study and an eco-charcoal production venture.

Keywords: climate-smart agriculture, human–wildlife conflict, integrated landscapes, Kasigau corridor, Tsavo ecosystem

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OVERVIEW OF THE NEXUS IN DRYLANDS

Humanity requires food and water for existence, while energy is a primary driver for economic development. A growing human population, rapid economic growth and increasing prosperity and consumerism are driving up demand for food, water, and energy globally (Ozturk, 2015). The ability of existing food, water, and energy systems to meet this growing demand is constrained by the competing needs for limited resources across the different sectors. Increasingly, it has been shown that issues in the food, water, and energy sectors are closely interwoven and cannot be managed effectively without cross-sectoral integration. In South Asia for instance, Rasul (2014) demonstrated a high degree of dependency of downstream communities on upstream ecosystem services for dry-season water for irrigation and hydropower, drinking water, and soil fertility and nutrients. Globally, agriculture is the largest consumer of water, while energy is required to produce and distribute water and food; energy production such as, hydropower also requires water. As such, exploiting synergies and balancing trade-offs between food production systems and water and energy use is critical for ensuring security across the three spheres (WWAP, 2014). The nexus as used in this paper describes the point food, water, and energy systems intersect.

At this intersection, actions related to one system can, and often will, impact one or both of the other systems, making it useful to take a nexus (holistic) approach when implementing such actions. Indeed, there is increasing evidence that improved food, water, and energy security can be achieved through a nexus approach that integrates management and governance across sectors and scales, which decreases negative economic, social, and environmental externalities (Hoff, 2011). This approach recognises the interdependencies of food, water, and energy production systems, providing a good framework for assessing resource use and improving sustainability by managing trade-offs and enhancing synergies (Hellegers et al., 2008; Bazilian et al., 2011; Biggs et al., 2015). It enables decision-makers and practitioners consider cross-sectoral impacts, where co-benefits and trade-offs are made explicit, and appropriate safeguards put in place to reduce the risk that progress toward one goal will undermine progress toward another (WWAP, 2014).

Moreover, major changes are occurring with important implications for the status of the food–water–energy interface (Hellegers et al., 2008). Changing land use systems and climate variability will increase stresses on the entire nexus at multiple spatial scales, while water shortages are expected to worsen with climate change, forest loss, and growing urbanisation (Tidwell, 2016). However, the role of the food–water–energy nexus in adaptation to climate change effects has perhaps not yet been fully recognised (Rasul and Sharma, 2016). The Sustainable Development Goals (SDGs) ultimately target achieving sustainable agricultural practices, water, and energy security; indeed, the food–water–energy nexus was central to discussions regarding the development and subsequent monitoring of the SDGs (UN, 2014). This nexus underscores the linkages and relationships between the natural and human systems, particularly in the development of economically and environmentally feasible food and energy production systems. In the drylands of Africa, human–wildlife conflicts (HWCs) lie at the heart of these human–natural systems' interface (Johansson, 2008).

A recent global assessment of drylands, which cover over 40% of Earth's land surface and support close to the same proportion of the human population, found that multifunctionality was positively and significantly related to plant species richness (Maestre et al., 2012). Still, almost all of the tropical dry forests today are exposed to a variety of threats including habitat loss and climate change (Miles et al., 2006; Bestelmeyer et al., 2015). Habitat loss and degradation is driven by a combination of factors, all relevant in the food–energy–water nexus. Agricultural production (both livestock and crops) coupled with fuelwood dependence (firewood and charcoal) can result in depleted water resources (e.g., see Rasul, 2016 for impact of agriculture on water and energy). Further, the co-occurrence of humans and elephants in these dryland ecosystems sets up the potential for conflict (**Figure 1**).

HOW DO WE RECONCILE THIS?

A fundamental issue here is the direct competition for resources: watching an elephant feed, move, or drink, one wonders just how they will survive in human-dominated and increasingly agricultural landscapes, even in the absence of poaching. While the circumstances under which it happens and its ramifications have long been debated (Caughley, 1976; Western, 1989), there is clear evidence of elephant destruction of forests and woodlands (e.g., Ben-Shahar, 1993; de Beer et al., 2006; Asner and Levick, 2012; de Boer et al., 2015; cf. Chamaillé-Jammes et al., 2009). These are the same resources required not only for fuelwood and charcoal, but also for climate moderation. Besides, elephants need up hundreds of litres of water a day, just for drinking; as rainfall patterns change, humans, and wildlife are also competing for diminishing water resources.

Historically, across multiple continents, megafauna are hardest hit by the combined impacts of climatic changes and human activities, since they typically are species with low reproductive rates and rely on high adult survival (Barnosky et al., 2004; Gibbons, 2004; Burney and Flannery, 2005; Barkham, 2016; van der Kaars et al., 2017). Crucially, the human population within the countries making up the elephant range in Africa (**Figure 1**) mostly live in rural areas (Martin, 2016). In most of these elephant range countries, the minimum human density for elephant co-existence (Parker and Graham, 1989) has been exceeded, resulting in population declines and severe range contraction of elephants (Douglas-Hamilton, 1987; Bouché et al., 2011; de Boer et al., 2013; Chase et al., 2016).

For the food–water–energy nexus, the germane question is whether the multiple goals can be attained in the midst of megaherbivores like elephants. In the face of the global concern and campaign to save the elephant, this is a socio-politically sensitive question to ask. Farmers in many parts are also feeling the pressure: they are unable to articulate their interests and fears, or indeed defend their crops and resources for fear of repercussions (e.g., Woodroffe et al., 2005). This is a major determinant for the nexus' success in drylands of Africa, and calls for holistic solutions that explicitly incorporate human–elephant conflict (HEC) into the frame.

RE-CASTING THE NEXUS PROBLEM FOR AFRICAN DRYLANDS

Humans and elephants are consummate competitors; competition theory maintains that such species cannot exist in sympatry (Parker and Graham, 1989). Indeed, with expanding permanent agriculture, HEC appears to be increasing in many African ecosystems as the agricultural interface with

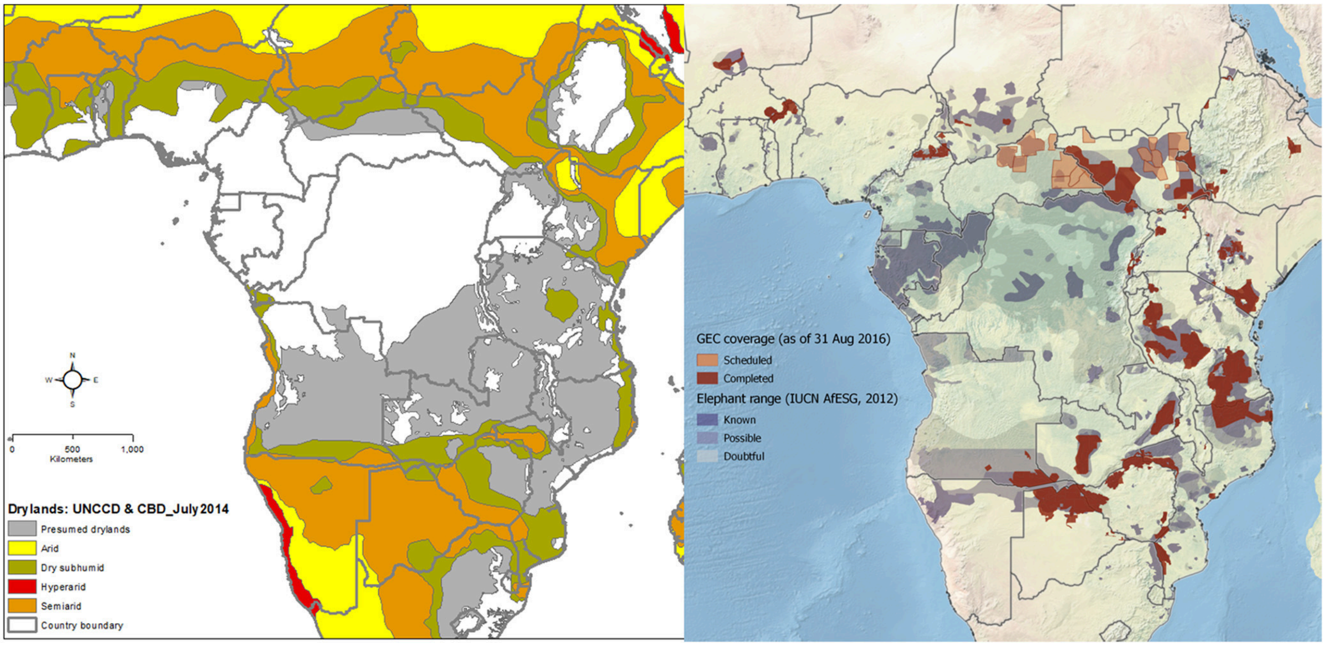

FIGURE 1 | African drylands and present-day elephant range; the drylands map adopted from UNEP-WCMC (2007), and the known elephant range map reproduced from Chase et al. (2016) and Thouless et al. (2016).

elephant range expands (Hoare, 1999; King et al., 2017). Yet, seemingly, many studies addressing food, water, and energy issues simultaneously do not consider human–wildlife conflict as a critical factor determining the outcome of any proposed solutions, for areas like the drylands of Africa where humans co-exist with elephants. This is exemplified in the following excerpt from a recent publication on drylands agriculture and climate change: *Against a backdrop of increasing climate change, a primary challenge for decision makers in the world's dry lands will be helping rural communities to earn a living and produce food securely in a situation where land is degraded, water scarce, and rainfall and temperature patterns increasingly unpredictable. Viable options and interventions exist today. They include using: improved crop varieties and livestock breeds; farming approaches to reduce risk and improve nutrition; making farming for communities living in on marginal lands more resilient; and methods for making the best possible use of the scarce water available* (Pedrick et al., 2012).

Likewise, in another seminal tome on multifunctionality in climate-smart landscapes—i.e., those that simultaneously support climate, agriculture, and conservation objectives (Scherr et al., 2012), wildlife hardly features; there are only few mentions of HWCs and their role in shaping land use outcomes in these human–natural ecosystems and landscapes (Minang et al., 2015). Although Minang and his colleagues highlight several examples of climate-smart landscapes where wildlife habitats or corridors are maintained in an otherwise agricultural matrix, only once do they mention that such diverse landscape objectives *could also influence each other negatively when wild animals damage crops grown by the farmers/agropastoralists.*

While the point of focus in these and similar publications is on the conflict for resources across the three sectors (food, water, and energy), we argue here that HEC deserves more than a cursory mention. In some situations, HEC is crucial in shaping the rest of the nexus. For instance, the scaling problem seen through low adoption or failure of farmers taking up climate-smart agriculture (CSA) and associated practices, even when they are demonstrated to have clear yield and productivity benefits (e.g., Lin, 2011; Kaczan et al., 2013), is a recurring theme. Usually, it can be traced back to HWC, and the fear or unwillingness of farmers to put effort and money toward crop production in the face of likely destruction by wildlife, especially elephants (e.g., Gupta, 2013).

Many nexus studies also recommend that landscapes and production systems could, perhaps should, be managed for multiple end uses, including habitat for wildlife and other ecosystem services (Bennett and Balvanera, 2007), yet few explain how the system will actually function on the ground (cf. Smajgl et al., 2016). Likewise, the integrated landscape management (ILM) approach seeks to achieve multiple objectives from a landscape, including agricultural production, provision of ecosystem services, and protection of biodiversity (Scherr et al., 2013). This calls for different stakeholders to weigh competing demands and balance trade-offs between diverse land uses and objectives. It has been suggested that, within such integrated landscapes: *Sustainably managed and lightly used habitat for native plants, birds, bees and beasts provides critical ecosystem services like pollination, pest predation, and wildfire and land slip* *protection, along with being culturally significant, beautiful and valuable in its own right* (LPFN, 2015).

Besides no mention of potential problems with this set up, it is also unclear how it is to be implemented on the ground. The outlined recommendations for action (LPFN, 2015) do not indicate how to resolve the thorny HWC issues that would often accompany these landscapes, if they are successfully established. For elephants in particular, there are numerous examples in Africa and elsewhere of the economic and social losses to human societies associated with living in close proximity with them. These range from economic (mainly crop-related) losses (Sitati et al., 2003; Sitienei et al., 2014), social (Naughton et al., 1999), health (Jadhav and Barua, 2012), and sometimes multiple effects (Mackenzie and Ahabyona, 2012).

As such, it is worth asking: for whom is the landscape being structured (e.g., Githiru, 2007). The farmer will almost always see elephants as a nuisance; a dangerous and destructive pest (Twine and Magome, 2008). If farmers perceive an inordinate risk of crop damage by wildlife, farming could be altered or abandoned entirely despite suitable technology, seeds, etc. (see e.g., Williams, 2009; Gupta, 2013; McGuinness and Taylor, 2014; Vidija, 2017). What then would be their motivation to build a multifunctional landscape that jeopardises their fields even whilst conserving wildlife and wildlife habitats? At a policy level, this could also be seen from the perspective of revenue-sharing regarding the commons (sensu Hardin, 1968), whereby elephants destroy the farmer's *own* crops, but the bulk of tourism revenues go to the *State* before trickling back to the community (also in the collective sense), if they do.

We postulate that, if the integrated landscape idea was written by a farmer, it would have a very different design. Perhaps the reason HWC hardly features in these conversations, besides perhaps an inadvertent underrating of the magnitude and ramifications of the problem, is the thorny nature of any solutions (e.g., Hoare, 2012). Nonetheless, we believe that the problem should be brought to the fore in conversations around the food–water–energy nexus in drylands of Africa, if we are to have a more complete picture of trade-offs, and a better understanding of the reasons for poor uptake of certain recommendations by farmers and government agencies.

CASE EXAMPLE: ELEPHANTS AND CSA, SE KENYA

In the expansive Tsavo ecosystem, SE Kenya, we have recently begun an initiative that hopes to explicitly build-in the HEC issue into some elements of the food–water–energy nexus. The primary goal of the project is working out how the dryland forest ecosystem and surrounding agricultural matrix along the Kasigau Corridor REDD+ project[1] landscape can retain their critical ecological functions and services, including the vital wildlife corridor function, whilst simultaneously supporting resilient livelihoods. The major drivers of deforestation justifying the REDD+ project were identified as charcoal production and slash-and-burn agriculture (WWC, 2011). While the later happens in frontier areas typically prone to HEC, there are additional HEC issues for more established farms due to increased degradation of elephant habitat and reduced connectivity especially due to mega-infrastructure projects. As such, though a key point of entry into the food–water–energy nexus in this context is charcoal production, both social (income source) and biological (habitat degradation) aspects, dealing with this issue demands looking at root causes. An important root cause here is HEC's influence on farming decisions and impact on yields. Consequently, the ongoing study is moulded around the following objectives related to the nexus and HEC:

- Food, Water, and Energy: Develop the applied science of sustainable intensification of crop production using CSA, mainly involving crop diversification and agro-forestry for multiple benefits including better yields, improved water use and retention, as well as provision of fuelwood[2].
- Food and HEC: Assess the effectiveness of various low-technology deterrents, working independently or in combination, in reducing both crop damage and averting HECs.
- Biodiversity conservation and HEC: Investigate how elephant ecological research and monitoring can contribute to mitigating for HEC. This involves collecting and collating elephant population, movement, and behaviour data, which will lay the scientific foundation for an early warning system disseminated through SMS alerts and a system of warning lights.

This study hopes to give recommendations for improved food production under CSA, such as, the use of different crops or crop varieties, agro-forestry, and water retention methods like conservation agriculture, and how this can be combined with energy production and a reduction in HEC-related losses. We hope to help design a system where farmers can produce more on their farms by needing or using less water and adequately guarding against HEC, but also satisfy their energy needs from the same food production system. From the food–water–energy nexus perspective, it aspires to stop the vicious cycle where poor crop production leads to low income, which leads to habitat attrition for charcoal production, in turn leading to increased HEC and even lower yields.

CONCLUSION

It is worth reiterating here that the core thrust of this paper mainly concerns the drylands of Africa where agricultural lands lie adjacent to wildlife areas and are prone to human–wildlife conflict, especially as pertains to elephants. Perfect-looking solutions for the food–water–energy nexus in these areas e.g., integrated landscapes involving increasing tree cover and crop diversification that help increase productivity and conserve

[1]The REDD+ project area covers 2,000 km^2 of *Acacia-Commiphora* dryland forest, with a human population of about 100,000 living adjacent to this area (WWC, 2010, 2011).

[2]Alongside this is a separate effort developing a simple eco-charcoal production technology that the farmers can apply on their farms to make charcoal and briquettes for subsistence and small-scale commercial use.

water resources, will remain under or un-implemented if they contribute to, or are perceived by the farmers to contribute to, increased HWC. While poaching remains an extremely emotive subject, loss of habitats, and associated HEC are perhaps more insidious, relentless, and remorseless. As the human population in Africa grows, our ability and willingness to share land and the life-supporting resources with this megaherbivore will be frequently and severely tested. If multifunctional landscapes are to stand a chance, the whole food–water–energy nexus for drylands of Africa will need to be recast, considering the elephant in the room.

AUTHOR CONTRIBUTIONS

MG: Contributed to all aspects of the work including conception and design, fieldwork for case study and interpretation of community views, drafting the work and revising it critically. He gave a final approval of the version to be submitted, and consented to be accountable for all aspects of the work. UM: Contributed to conception and design, drafting the work and revising it critically. He gave a final approval of the version to be submitted, and consented to be accountable for all aspects of the work. SK: Contributed to fieldwork for case study and interpretation of community views, drafting the work and revising it critically. He gave a final approval of the version to be submitted, and consented to be accountable for all aspects of the work. BS: Contributed to conception and design, drafting the work and revising it critically. He gave a final approval of the version to be submitted, and consented to be accountable for all aspects of the work.

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