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Charcoal is the main cooking fuel for urban populations in many African countries. Urbanization and population growth are driving an increase in demand for charcoal, whilst deforestation reduces biomass stocks. Given increasing demand for charcoal, and decreasing availability of biomass, policies are urgently needed that ensure secure energy supplies for urban households and reduce deforestation. There is potential for charcoal to be produced sustainably in natural woodlands, but this requires supportive policies. Previous research has identified policy issues that have contributed to the charcoal sector remaining informal and environmentally destructive. In this paper, we describe how national policies in Tanzania on energy, forests, agriculture, land, and water, consider charcoal, and the degree to which they do, and do not, support sustainable charcoal production. The paper identifies policy gaps and a cross-sector tendency to marginalize natural forest management. By adopting a nexus approach, the paper highlights the inter-connections between sustainable charcoal production, ecosystem services, and trade-offs in the allocation of land, labor, and net primary production. In conclusion, sustainable charcoal production has been marginalized in multiple national policies. As a result, potential benefits of sustainable charcoal production are lost to multiple sectors.

Keywords: charcoal, sustainable forest management, policy analysis, nexus, Tanzania

INTRODUCTION

Global wood charcoal production has trebled over the last 50 years from 17.3 million tons in 1964 to 53.1 million tons in 2014 (FAO, 2016). Sixty-one percent of current global production occurs in Africa (FAO, 2016), primarily to satisfy demand for cooking fuel from urban and peri-urban households (Mwampamba et al., 2013; d'Agostino et al., 2015). With Africa's population projected to double between 2015 and 2050 (UN, 2015), and with increased rural-urban migration in key producing countries, including Tanzania, Ethiopia, and Nigeria (FAO, 2016), demand for charcoal is projected to increase. Whilst demand for charcoal is projected to increase in Africa (IEA, 2014), the availability of woody biomass is declining due to widespread net deforestation (Hansen et al., 2013).

Charcoal can be produced without permanently deforesting or degrading a forested area, by protecting harvested areas from cultivation, intensive grazing, and fire, thus enabling natural regeneration. We use the term "to deforest," to mean the long-term or permanent removal of forest cover and conversion to a non-forested land use (Watson et al., 2000), whilst we follow the FAO (2003) definition that forest degradation means the long-term reduction of the overall potential supply of benefits from a forest, which includes carbon, wood, biodiversity, and other goods and

services. As Chidumayo and Gumbo (2013) have stated, woodlands in many tropical countries, including Tanzania, will regenerate within 8–30 years of trees being cut for charcoal. Similarly, Woollen et al. (2016) found that areas of Mopane woodland in Mozambique, under long term charcoal production, continued to provide most ecosystem services, so long as the woodland species continued to dominate the area.

Sustainable charcoal production requires owners of natural woodland to maintain forest cover over time, rather than converting it to other land uses, such as agriculture. In this paper, we assume that charcoal production is more likely to be sustainable if charcoal-dependent countries adopt, and implement, policies that explicitly support sustainable production and incentivize forest owners to maintain natural woodland for sustainable charcoal production. We assume that sustainable production is more likely to be achieved in woodlands with secure tenure, formalized management, and harvesting plans designed to maintain the broad ecosystem functions of the forest or woodland. This assumption is supported by evidence from Niger and Senegal, where the adoption of formalized, community-based woodfuel production has resulted in an increase in the forest stock (de Miranda et al., 2010). In contrast, in Tanzania and in many of the other top charcoal-producing countries in Africa, charcoal value chains are largely informal with production proceeding in the absence of sustainable harvesting plans (Sander et al., 2013; Schure et al., 2013). The informality of production, particularly the absence of formalized and sustainable harvesting, has contributed to widespread forest degradation and, to a lesser extent, deforestation, particularly in the vicinity of concentrated markets, such as large urban areas (Chidumayo and Gumbo, 2013). The role of national policy, in this context, is to document a nation's intention to manage natural forests for sustainable charcoal production, with lower level policy tools setting out the details of how the policy should be implemented. National policy therefore provides a foundation for the formalization of sustainable charcoal production, and for the allocation of forest lands for that purpose. If these assumptions are correct, then we can infer that embedding sustainable charcoal production in national policy will help to safeguard forests, and the ecosystem services that they provide. However, we also recognize that formalization does not guarantee sustainability (Schure et al., 2013), and that there are examples of government attempts to control supply which have, instead, disrupted supply (Ribot, 1999), and of informal production in which forest ecosystem services are sustained (Ribot, 1999; Woollen et al., 2016). We also recognize that there are currently few examples of formalized, sustainable charcoal production in practice (de Miranda et al., 2010; Zulu and Richardson, 2013). The relevance of including sustainable charcoal production in national policy and the risks of omitting it are explored throughout the paper. Despite the potential benefits of sustainable charcoal production, national policies

in many African countries have not embraced the practice even in countries with development programmes, and research, promoting sustainable production [World Bank, 2009; Owen et al., 2013; Sander et al., 2013; CamCo Clean Energy (Tanzania) Limited, 2014].

There are various reasons why sustainable charcoal production has been marginalized in national policies. Mwampamba et al. (2013) identified five misconceptions about charcoal that are held by policy-makers and other stakeholders, despite evidence that runs counter to those perceptions. These include beliefs that: charcoal is an energy source primarily for the poor; that charcoal use for cooking will decrease automatically, as a country becomes more developed; that charcoal production causes deforestation; that the charcoal sector is economically irrelevant; and that improved charcoal cook stoves mitigate deforestation. The authors highlight that a paucity of data on the charcoal trade has confounded attempts to nurture a more nuanced understanding of the trade amongst some policy-makers, and that, as a result, these beliefs have resulted in mis-guided policies. The question of why policy-makers have marginalized sustainable charcoal production in national policy is also explored in this paper.

Various authors, including Mwampamba et al. (2013) and Sander et al. (2013), have highlighted policy-related barriers to improving the sustainability of charcoal production in Tanzania. In this study, we retain their focus on Tanzania whilst defining more precisely those policy-related barriers. We describe how charcoal is currently addressed in energy, forest, agriculture, water, and land policies in Tanzania. We also update previous analyses by bringing in the National Energy Policy, 2015 (URT, 2015b), and the draft National Forest Policy, 2014 (URT, 2014), and broadening the scope of the analysis also to consider the land, agriculture, and water policies. We assess the degree to which different sectoral policies consider sustainable management of natural woodlands for charcoal production. In addition to looking at policy content, we also look briefly at the broader policy cycle in order to identify other factors that have influenced the treatment of charcoal in national policy. By applying nexus thinking, we explore the inter-sectoral implications of current policies. We highlight the inter-connections between sustainable charcoal production, natural woodland management, ecosystem services, and the energy, forest, agriculture, water, and land sectors, particularly when viewed through the lens of climate change.

The paper is focused on policies in Tanzania, the fifth largest charcoal producer in Africa (FAO, 2016). Tanzania stands out in terms of the extent to which charcoal has contributed to deforestation in the country. For example, in a study of 17 countries with the highest deforestation rates globally, the average proportion of deforestation attributable to charcoal was $6.9 \pm 2.3\%$, with the highest proportion occurring in Tanzania at 33.16% (Chidumayo and Gumbo, 2013). However, the assumptions underpinning this estimate are only weakly validated, in terms of the interplay between charcoal and crop production, particularly in areas where charcoal production occurs during a land use transition from forest to cropland. Bailis et al. (2015) estimated that woodfuel harvesting contributed no

Abbreviations: CBFM, Community Based Forest Management; MNRT, Ministry of Natural Resources and Tourism; TFCG, Tanzania Forest Conservation Group; TFS, Tanzania Forest Services Agency; TZS, Tanzanian Shilling; VLFR, Village Land Forest Reserve.

more than 20% of non-renewable biomass harvested in Tanzania. In the paper, we unpick some of the policy-related drivers of deforestation and forest degradation. We also challenge policy makers, in countries such as Tanzania that are undergoing rapid economic and land use change, to re-evaluate the land use trade-offs that are being made between agriculture and natural forests, and to embrace policies that promote sustainable charcoal production and natural woodland management.

Charcoal and the Energy Sector

The nexus between charcoal and the energy sector in many African countries, including Tanzania, centers on its predominance in the national energy supply. Woodfuels including charcoal and fuel wood provide 85–90% of Tanzania's energy supply (World Bank, 2009; URT, 2015b). In urban areas, 71% of households depend on charcoal, whilst fuelwood is predominantly used in rural areas [CamCo Clean Energy (Tanzania) Limited, 2014]. Tanzania's urban population has increased from <1 to 12 million over the last 50 years (FAO, 2016). This growth trend is projected to continue, with a concomitant increase in the proportion of the population using charcoal (Sander et al., 2013).

Charcoal and the Forestry Sector

Perceptions of the charcoal–forest nexus have focused on forests as an input to charcoal production, and the impact, thereof, in terms of deforestation and forest degradation (Msuya et al., 2011; Mwampamba et al., 2013; Owen et al., 2013). Less attention has been paid to the potential for charcoal to generate revenues for sustainable natural woodland management, thereby contributing to the retention of forest cover. This can be attributed to the low level of effort that has been made in managing woodlands sustainably for charcoal production. This has created a “vicious cycle,” where the *status quo* of unplanned production is perceived to be the only production model. This leads policy-makers to marginalize, and occasionally attempt to ban charcoal (Mwampamba et al., 2013), thereby missing the opportunity to generate revenues for investment in sustainable management, including in the context of community-based forest management. The lack of investment in forest management perpetuates the unplanned production model, and so reinforces its negative impact on the forest resource base. From a climate change perspective, the absence of sustainable forest management results in the emission of greenhouse gases from the resultant deforestation and forest degradation (Bailis et al., 2015).

Charcoal and the Agriculture Sector

The nexus between charcoal and the agriculture sector centers on the allocation of land, labor, and net primary production. The outcome of the nexus between agriculture and charcoal has important implications for forests, given that agriculture generally results in the conversion of forests to cropland i.e., deforestation, whilst charcoal production is more frequently a driver of forest degradation (Ribot, 1999; Chidumayo and Gumbo, 2013; Woollen et al., 2016). At one level, agriculture and charcoal production compete with each other for land, labor, and net primary production, albeit for the common

purpose of feeding people. However, whilst sustainable charcoal production requires post-harvesting regeneration of woodland, crop production results in deforestation. Sustainable charcoal production from natural woodlands is existentially dependent on the continued availability of those woodlands, and, by default, the ecosystem services generated by those woodlands (Figure 1).

Although data on the proportion of deforestation attributable to specific drivers is not readily available in many countries (Hosonuma et al., 2012), there is considerable evidence to demonstrate that agriculture is the main driver of deforestation in Africa, even in countries, such as Tanzania, where charcoal has also been identified as a significant deforestation driver (Gibbs et al., 2010; Chidumayo and Gumbo, 2013; Krausmann et al., 2013; Willcock et al., 2016). The question of whether, and how much, deforestation is caused by charcoal production, has been raised by several authors (Ribot, 1999; Mwampamba et al., 2013) and raises complex semantic issues (Lund, 2015), as well as unpicking the spatially heterogeneous inter-play of drivers of land use change. The availability of higher resolution and more frequent remote sensing images is helping to generate a more robust, and finer scale understanding of land use change, including deforestation (Hansen et al., 2013).

Whilst crop production is a major driver of deforestation, it is also dependent on the ecosystem services that forests provide, such as regulation of water quality and flow, protection of soils from erosion, and provision of habitats for pollinators and predators of crop pests (Foley et al., 2005; Ninan and Inoue, 2013). As such, forests play a binding role in the nexus between charcoal and agriculture, particularly when we consider the hydrology of agricultural areas. The linkages between forest cover and the hydrology of an area are complex and vary between catchments (Brown et al., 2005; Price, 2011). Maintaining forest cover reduces the risk and severity of flooding in many catchments (Bradshaw et al., 2007), and sustains base flows in some catchments, particularly those prone to soil hardpan formation and soil compaction, when deforested (Bruijnzeel, 1988; Price, 2011). Deforestation therefore has implications for downstream agricultural production, particularly for areas under irrigation. With climate change, the risks to agricultural production due to fluctuating dry season flows are likely to increase with the longer, drier dry season predicted for parts of Africa, including parts of Tanzania, by some climate models (de Wit and Stankiewicz, 2006; Watkiss et al., 2011). Therefore, policies that promote incentives to maintain forest cover, including sustainable charcoal, may also contribute to safe-guarding dry-season irrigation in downstream agricultural areas.

The nexus between charcoal and crop production is bound further by their common labor force. CamCo Clean Energy (Tanzania) Limited (2014) estimate that 300,000 households are involved in charcoal production in Tanzania.

Most charcoal producers are also farmers who practice charcoal production in the dry season (Zulu and Richardson, 2013). Charcoal production also provides an economic safety net for farmers in case of crop failure or others shocks to a household's livelihood (*ibid*; Jones et al., 2016). This points to the potential for sustainable charcoal production to enhance

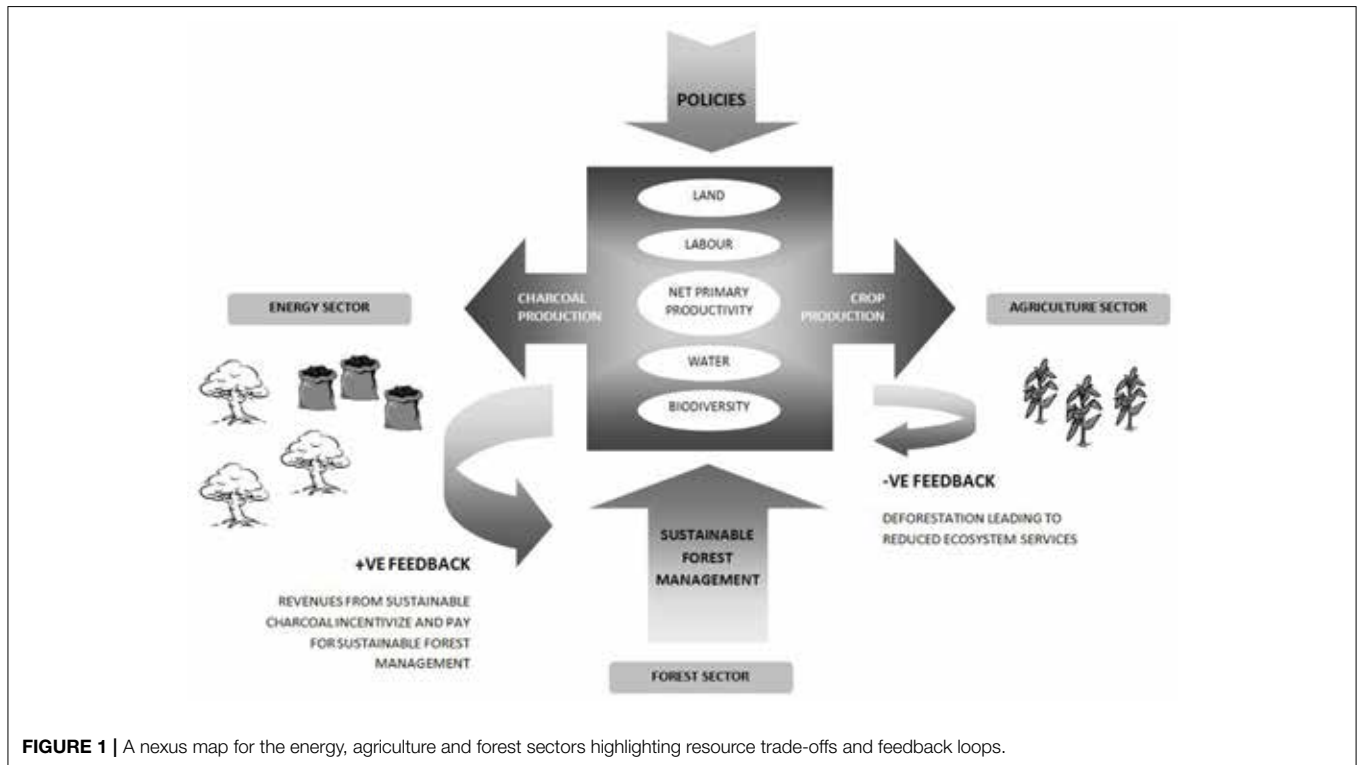


FIGURE 1 | A nexus map for the energy, agriculture and forest sectors highlighting resource trade-offs and feedback loops.

livelihood resilience in rural households vulnerable to climate change-related shocks.

The trade-off between charcoal production and agriculture is also influenced by land policy. Sustainable charcoal production requires national land policies that promote sustainable woodland management as a land use, and promote secure forest tenure, over a timescale proportionate to the 8–30-year woodland regeneration cycle. In this paper, we examine this nexus between charcoal, energy, forests, agriculture, land, and water, and the degree to which these connections are reflected in national policy.

METHODS

We apply an interpretive approach to policy analysis (Yanow, 2007), specifically a close-reading of policy documents. We selected Tanzania as a case study due to its high dependency on charcoal amongst urban households, the high potential for scaling up sustainable charcoal production given extensive areas of woodland in the country, and the authors' familiarity with the charcoal trade in Tanzania through involvement in the ongoing "Transforming Tanzania's Charcoal Sector project" financed by the Government of Switzerland.

We reviewed over-arching national policies including the constitution (URT, 1977), development vision (URT, 1999), and national climate change strategy (URT, 2012). We reviewed the national policies for the energy, forest, agriculture, land, and water sectors. We reviewed each national policy document for references to sustainable charcoal production, natural

forest management, charcoal, forest produce, woodfuel, biomass energy, and/or other terms with a similar meaning. For those sectoral policies that referred to any of these terms, we reviewed additional policy instruments including regulations, orders, guidelines, strategies, and plans. Text referring to those terms was compared to identify similarities and differences between policies. We compared the ways in which those terms are, or are not, presented in the policy background descriptions, issues, objectives, and statements. In our comparison, we also looked for statements on inter-sectoral connections related to sustainable forest management and/or the charcoal trade. The list of policy documents that we reviewed is provided in **Table 1**. We focused on charcoal produced from natural woodlands, rather than charcoal from plantations or fuel briquettes. We have followed FAO (2004) in its definitions of charcoal and fuelwood. However, we use a narrow definition of woodfuel to mean solid, direct woodfuels, specifically charcoal and firewood.

By looking at policy content, we focused primarily on the policy formulation and decision-making stage of the policy cycle, and to a lesser degree, the agenda-setting and implementation steps. The policy cycle provides a conceptual framework based on a simplified chronology of the policy process. Jann and Wegrich (2007) present a 5-step policy cycle model comprising: agenda-setting, policy formulation and decision-making, implementation, evaluation, and termination. Agenda-setting is the process by which issues are selected, or rejected, for inclusion in a particular policy. Research on agenda-setting might look at how policy makers select the issues to include in, or exclude from, national policy, and in which policy to include those issues. Research on agenda-setting also addresses political

TABLE 1 | Tanzanian policy documents reviewed.

OVER-ARCHING POLICY DOCUMENTS
The Constitution of the United Republic of Tanzania, 1977, Cap 2 (URT, 1977)
The Tanzania Development Vision 2025 (URT, 1999)
The National 5 Year Development Plan 2016/17–2020/21 (URT, 2016a)
ENERGY
The Rural Energy Act, 2005. Act No. 8 of 2005
The National Energy Policy, 2015 (URT, 2015b)
The National Energy Policy, Draft 2013
The National Energy Policy, 2003 (URT, 2003)
The Biomass Energy Strategy for Tanzania, Draft 2014 [CamCo Clean Energy (Tanzania) Limited (2014)]
Ministry of Energy and Minerals: Strategic Plan 2011/12–2015/16. MEM, 2011 (TFS, 2013b)
AGRICULTURE
The National Agriculture Policy, 2013 (URT, 2013a)
The National Livestock Policy, 2006 (URT, 2006)
LAND
The National Land Policy, Draft 2016 (URT, 2016b)
The National Land Policy, 1997 (URT, 1997b)
The Land Act, 1999. Act No. 4 of 1999. Cap 113
The Village Land Act, 1999. Act No. 5 of 1999. Cap 114
WATER
The National Water Policy, 2002
The Water Resources Management Act, 2009. Act No. 11 of 2009
FOREST
Forest Policies
The National Forest Policy, 1998 (URT, 1998)
The National Forest Policy, Draft 2014 (URT, 2014)
Forest Laws and Regulations
The Forest Act, 2002, Act No. 14 of 2002, Cap 323
The Forest (Amendment) Regulations, GN 324 of 2015
The Forest (Amendment) Regulations, GN 433 of 2013
The Forest (Amendment) Regulations, GN 69 of 2006
Forestry Sector Guidelines and Public Notices
<i>Community-Based Forest Management Guidelines</i> . Forestry and Beekeeping Division, 2007
<i>Joint Forest Management Guidelines</i> . Ministry of Natural Resources and Tourism, 2013
<i>Guidelines for Harvesting in Village Land Forest Reserves</i> . Tanzania Forest Services Agency, 2013 (TFS, 2013a)
<i>Public Notice regarding procedures for trade in forest products</i> . Tanzania Forest Services Agency, 2015
<i>Mwongozo wa uvunaji endelevu na biashara ya mazao ya misitu yanayovunwa katika misitu ya asili</i> (Guidelines on sustainable harvesting and trade in forest products from natural forests). Tanzania Forest Services Agency, 2015
<i>National Woodfuel Action Plan</i> . Forestry and Beekeeping Division, 2009. Draft
Tanzania Forest Services Agency Strategic Plan. July 2014–June 19. Tanzania Forest Services Agency, 2013
Other Forestry Sector Reports
Participatory forest management in Tanzania: facts and figures. Ministry of Natural Resources and Tourism, 2012

(Continued)

TABLE 1 | Continued

<i>The National forest resources monitoring and assessment of Tanzania Mainland: main results</i> . Ministry of Natural Resources and Tourism, 2015
<i>Maelezo kuhusu Wakala wa Huduma za Misitu, Tanzania: majukumu, mafanikio, changamoto na mikakati</i> (2011–2015) [Information about the Tanzania Forest Services Agency: responsibilities, achievements, challenges and strategies (2011–2015)]. Ministry of Natural Resources and Tourism, 2016
ENVIRONMENT AND CLIMATE CHANGE
The National Environmental Policy, VPO, 1997 (URT, 1997a)
The Environmental Management Act, 2004. Act No. 20 of 2004. Cap 191
The Draft National Environment Policy 2016 (URT, 2016c)
The National Climate Change Strategy, 2012 (URT, 2012)

questions in terms of whose issues make it onto the policy agenda, and who defines those issues. This flows into the policy formulation and decision-making step, which involves making choices about the purpose of a policy and the broad strategy to be pursued, in order to achieve those objectives. Once policy has been defined, the next step is for it to be implemented, including defining the regulatory, financial, and organizational details and enacting the strategies and plans. Policy implementation research includes looking at the way in which a policy is enacted, including its impact, cost-effectiveness, and inter-play with other policies. The evaluation and termination steps of the policy cycle cover the process of reviewing a policy and the subsequent steps of policy change. In reality, the steps are frequently overlapping, particularly when looking at an issue such as charcoal which cuts across multiple sectors each following its own unique policy cycle. The policy cycle framework has been criticized for being over-simplistic, top-down, and insensitive to context. It has also persisted in policy research, as a heuristic device, within which a plethora of quantitative and qualitative methods may be applied. Whilst recognizing its shortfalls, we find it to be a useful framework within which to position our research.

RESULTS

Tanzania's Development Vision as Determinant of Sector Policies

National policies are designed to guide a sector to play its part in achieving a broader national vision. As context for the paper's review of individual sectors, it is important to understand Tanzania's development vision as a key determinant of policy content. Tanzania's Development Vision 2025 aims at achieving "a high quality livelihood for its people, attain good governance through the rule of law and develop a strong and competitive economy" (URT, 1999).

In terms of economic development, it is envisaged that by 2025, "The economy will have been transformed from a low productivity agricultural economy to a semi-industrialized one..." In terms of economic targets, the Vision states that by 2025 there will be "a diversified and semi-industrialized economy with a substantial industrial sector comparable to typical middle-income

countries.” It is also envisioned that “fast growth will be pursued while effectively reversing current adverse trends in the loss and degradation of environmental resources (such as forests, fisheries, fresh water, climate, soils, biodiversity).” The national development vision is further elaborated in Tanzania’s current 5 year development plan which includes targets to “reduce charcoal consumption in urban areas by 30% by 2020/21 and by 60% by 2025/26,” as well as to “promote... renewable green energy technologies (biogas, LPG, Solar Energy).” Overall, the vision equates modernity with a shift away from the *status quo* where 75% of the work force is employed in an agriculture sector dominated by subsistence, small-scale crop production (URT, 2013a) and toward industrialization and a higher quality of life.

Woodfuel and Charcoal in National Policies

We found that, at policy level, no current national policies include objectives, or statements, giving specific directions on sustainable charcoal production. The word “charcoal” appears in the National Forest Policy, 1998 (URT, 1998) ($N = 2$), and the National Energy Policy, 2015 (URT, 2015b) ($N = 5$), seven times. Six of these seven occurrences are in the sector descriptions and outline the general importance of charcoal as an energy carrier in Tanzania, or its role in environmental degradation. One forest policy direction makes specific reference to restricting the export of charcoal. These statements are cited in **Table 2**. The Environmental Policy, 1997, uses the broader term “woodfuel” rather than charcoal, and provides the most comprehensive guidance, including policy objectives to “minimize woodfuel consumption and develop alternative energy sources and woodfuel energy efficiency and to promote rational exploitation of forest resources accompanied with reforestation and afforestation programmes...for domestic consumption and export...” The terms charcoal and woodfuel do not occur in the constitution and development vision, nor in the agriculture,

livestock, land, or water policies. Overall, there is consistency between the energy, forest, and environmental policies which present charcoal as an environmental problem to be resolved primarily through fuel-switching. **Table 3** provides an overview and timeline of the policies and other key regulatory documents included in this review.

Consideration of cross-cutting issues, including environment, began to be a standard component of national policies in Tanzania after 2003 (URT, 2003). Thus, older policies, such as those for land, forest, and water, do not include sections on cross-cutting issues, whilst the more recent agricultural, livestock, and energy policies include policy objectives and statements related to the environment as a cross-cutting issue.

Sustainable Charcoal Production and the National Energy Policy

The focus on fuel-switching is exemplified in the mission of the National Energy Policy, 2015 (URT, 2015b), which is, “To provide reliable, affordable, safe, efficient and environment friendly modern energy services to all while ensuring effective participation of Tanzanians in the sector.” Modern energy is defined as “energy that is based on petroleum, electricity or any other energy forms that have commercialized market channels, a higher heating or energy content value than traditional energy.” In its policy statements, biomass is only included in relation to the objective of enhancing the utilization of renewable energy resources so as to increase its contribution in diversifying resources for electricity generation (URT, 2015b). A focus on fuel-switching from biomass to other energy carriers has remained consistent in Tanzania’s national energy policies over the last 25 years. However, the 2015 policy differs from the 1992 and 2003 energy policies in excluding any objective related to sustainable production of woodfuels, except in the context of electricity generation. For example, the National Energy Policy, 2003 (URT, 2003), included the guiding statement “promote efficient biomass conversion and end-use technologies in order to save resources; reduce rate of deforestation and land degradation; and minimizing threats on climate change.”

Between 2010 and 2014, the Government of Tanzania developed a biomass energy strategy and action plan, with financial support from the European Union. The primary goal of the strategy was, “To make biomass energy sustainable in Tanzania.” The strategy proposed five activity bundles aimed at “ensuring that biomass energy is sustainable in Tanzania along the entire value chain,” including sustainable charcoal production. However, as of May 2017, the strategy had not been adopted. Policies were also drafted for petroleum, natural gas, and renewable energy, of which the natural gas policy was approved, whilst others remained in draft form. These policies were then merged into the National Energy Policy, 2015 (URT, 2015b; Muhongo, 2016). Solid biomass energy was excluded from the National Energy Policy during the final stages of the policy revision process. A consultative draft of the National Energy Policy included a policy objective, “To enhance production and rational use of solid biomass resources,” and a policy statement, “Encourage sustainable production of solid biomass” (URT,

TABLE 2 | National policy statements that include the term “charcoal.”

National Forest Policy, 1998 (URT, 1998)

2.0 Main sectoral problems and opportunities

The main reasons for deforestation are clearing for agriculture, overgrazing, wildfires, **charcoal** burning and over-exploitation of wood resources

4.2.5 Trade in forest products

Internal trade and export of certain forest products such as...**charcoal**..., may be restricted or remain under licensing until the conditions for sustainable forest management and utilization are in place

National Energy Policy, 2013

1.2 Energy situation in Tanzania

The national energy balance indicates dominance of biomass use in the form of **charcoal** and firewood and its contribution to the total national energy consumption is about 85 percent

Charcoal consumption mainly in urban areas has nearly doubled over the past 10 years due to urbanization, high prices or scarcity of other alternatives particularly kerosene, electricity and LPG. It is projected that demand for **charcoal**, without supply and demand side interventions will double by 2030, from approximately 2.3 million tons of **charcoal** in 2012. The Government has been promoting substitution of **charcoal** and firewood by providing tax relief to stimulate the use of LPG in the country

TABLE 3 | Timeline of key policy documents summarizing their position on sustainable charcoal.

1997	The National Environmental Policy, 1997 (URT, 1997a)	Objectives include, “ <i>Minimisation of woodfuel consumption through development of alternative energy sources and woodfuel efficiency,</i> ” (Energy); and “ <i>Rational exploitation of forest resources accompanied with reforestation and afforestation programmes shall be promoted</i> ” (Forestry) No specific mention of charcoal
	The National Land Policy, 1997 (URT, 1997b)	Land tenure tenet: “ <i>Rights and title to land...will be based mainly on use and occupation,</i> ” and, “ <i>Development conditions are imposed on holders of land</i> ” Community land rights: “ <i>Village Councils will administer village lands</i> ” No specific mention of charcoal
1999	The Land Act, 1999	Categorizes land as general, village, and reserved land No specific mention of charcoal
	The Village Land Act, 1999.	Grants village councils the “ <i>responsibility for the management of all village land.</i> ” Elaborates the definition of village land No specific mention of charcoal
2002	The Forest Act, 2002	Includes charcoal in the category “ <i>forest produce.</i> ” Sets the legal requirement that forest management plans be in place prior to harvesting any forest produce; empowers communities to manage, and sustainably harvest from, forests on village land; and grants exemption from Central Government royalties for forest products harvested in village land forest reserves
	The National Water Policy, 2002	Recognizes that “ <i>forests have an important effect on the conservation of water resources.</i> ” Deforestation cited as a cause of soil erosion and directs that awareness raising campaigns on good land use practices, be undertaken No specific mention of charcoal
2003	The National Energy Policy, 2003 (URT, 2003)	Charcoal classified as a renewable energy with the objectives, “ <i>Promote efficient biomass conversion and end-use technologies to ... reduce deforestation (Renewable Energy);</i> ” and, “ <i>Promote application of alternative energy sources other than fuelwood and charcoal, in order to reduce deforestation...</i> ” (Rural Energy)”
2004	The Environmental Management Act, 2004	Provides a general framework for environmental management and protection No specific mention of charcoal
2006	The Forest (Amendment) Regulations, 2006	Describe the procedures, and responsibilities of different entities, in relation to permits for the production, trade, and transportation of charcoal
2007	Community-Based Forest Management Guidelines, 2007	Include specific references to the integration of charcoal production in the management of village land forest reserves

(Continued)

TABLE 3 | Continued

2013	The Forest (Amendment) Regulations, 2013	Set the royalty for one 90 kg bag of charcoal at TZS 14,400; and the annual registration fee for a charcoal dealer at TZS 256,000
	Guidelines for harvesting in VLFRs, 2013	Provide guidance on how village land forests can be harvested. Primarily focused on timber, although charcoaling of timber off-cuts is mentioned
2015	The Forest (Amendment) Regulations, 2015	Set the royalty for one 75 kg bag of charcoal at TZS 16,600; and the annual registration fee for a charcoal dealer at TZS 256,000
	The National Energy Policy, 2015	Its mission is “ <i>to provide...modern energy services to all,</i> ” rather than traditional energy. Biomass energy is included under the objective “ <i>To enhance utilization of renewable energy sources...for electricity generation (Renewable Energy)</i> ”

2015a). During the stakeholder consultation process, Tanzanian Civil Society Organizations asked for the policy to provide even more guidance on charcoal and submitted specific proposals for text to be included in the policy (TFCG, 2015a). However, instead of providing more explicit guidance on charcoal, the objective on solid biomass resources was subsequently narrowed, solely to refer to biomass in the context of electricity generation. The result is a policy that, on the one hand, states that, “*The national energy balance indicates dominance of biomass use in the form of charcoal and firewood and its contribution to the total national energy consumption is about 85 percent,*” and, on the other hand, provides no specific guidance on how to manage that energy carrier.

Sustainable Charcoal Production and the National Forest Policy

The National Forest Policy, 1998 (URT, 1998), also recognizes the importance of woodfuels in the national economy whilst promoting fuel-switching, in its direction that, “*The use of alternative affordable sources of energy will be promoted through research and extension.*” In addition, the forest policy promotes the “*establishment of private woodlots and plantations for woodfuel production.*” Tanzania’s National Forest Policy, 1998 (URT, 1998), has been under review since 2008 when a zero draft was circulated to stakeholders for comments, with another draft circulated for comments in 2014, and a committee formed to finalize the policy in 2017. The lengthy revision process, in part, reflects the intervening transfer of forest management responsibilities from the Forestry and Beekeeping Division to the, more autonomous, Tanzania Forest Services Agency (TFS), which was established in 2010. In this paper, both the 1998 policy, and the 2014 draft policy document, are considered. Although in draft form, the 2014 policy is relevant as an indication of the policy direction being considered.

The four overall objectives of the 1998 policy include the objective, “*To ensure sustainable supply of forest products and services by maintaining sufficient forest area under effective management;*” and “*To ensure ecosystem stability*

through conservation of forest biodiversity, water catchments and soil fertility.” The policy includes policy objectives and statements reflecting a commitment to planned, sustainable forest management as a means to supply various forest products and ecosystem services, including charcoal. The goal of the 2014 draft forest policy, which has remained largely unchanged since 2008, is “enhanced contribution of the forest sector to the sustainable development of Tanzania and the conservation and management of her forest resources for the benefit of the present and future generations.” Of its four objectives, the most relevant objective of the 2014 draft policy is, “To ensure sustainable supply of forest products and services by maintaining sufficient forest under effective management.” As with the 1998 policy, the draft 2014 forest policy is supportive of community based forest management including sustainable production of charcoal and other forest products.

URT (2002) and supporting regulations, guidelines, and orders provide further policy support for sustainably managed, productive forest reserves, including village land forest reserves. For example, the Forest Act, 2002, empowers Village Councils (through the designated village committee) to establish productive village land forest reserves and to issue permits for the extraction of forest produce including charcoal, provided that sustainable management plans are in place. Since the 1990s, more than 530 Village Land Forest Reserves have been established (TFS, 2012 plus TFCG data), including 2.4 million ha of woodland and forest, however, until 2012, none had integrated sustainable charcoal production into their management plans. In part this can be attributed to a lack of guidelines on policy implementation, with policy guidelines on forest product harvesting in village land forest reserves focusing on timber, rather than on charcoal (TFS, 2013a). Since 2012, a project in Morogoro Region, led by the Tanzania Forest Conservation Group (TFCG), has been piloting sustainable charcoal production embedded in community-based forest management as a demonstration for scaling up to other village land forests.

In the context of woodfuel, the draft 2014 National Forest Policy (URT, 2014) states that, “Establishment of private woodlots and plantations, planting of trees on farm for wood fuel production, efficient wood energy conversion and use technologies and alternative sources of energy will be promoted.” As with other policies, there is a focus on fuel-switching and tree planting. Under the forestry sector, Tanzania’s 5-year development plan includes a target of increasing forest area by 130,000 ha by 2020/21 and 160,000 ha by 2025 through tree planting, for which it indicates a budget of TZS 150 billion and a target of 280 million trees/year, for implementation by the Government (URT, 2016a). The commitment to expand plantations is also reflected in the TFS strategic plan for 2014/19 which includes a target of 50,000 ha of new plantation by 2019 (TFS, 2013b). The 5-year Development Plan indicates that all other forestry sector activities including capacity building and nature reserve management should be paid for by Development Partners (URT, 2016a). Although the policy promotes planting of trees for wood fuel, in reality, most plantations are targeting the timber market, given a higher price per cubic meter for wood when sold as timber than as charcoal. As such, replacing charcoal

from natural woodlands with charcoal from plantations, is only likely to succeed at the point where charcoal becomes a more profitable end product than timber for plantation owners. The profitability of charcoal from plantations and woodlots relative to the profitability of timber and other forest products, is often overlooked by those proposing that planted trees be used in charcoal production.

Sustainable Charcoal Production and the National Agriculture Policy

The 2013 Agriculture Policy’s mission is, “to facilitate the transformation of the agricultural sector into a modern, commercial and competitive sector in order to ensure food security and poverty alleviation through increased volumes of competitive crop products” (URT, 2013a). The focus on transforming agriculture from traditional, subsistence crop production to a more intensive, commercialized system is aligned with the National Development Vision. The National Agriculture Policy states that, “by definition the agricultural sector is comprised of the crops, livestock, fisheries, forestry and hunting sub sectors,” it then goes on to limit its scope to “crop production.” Charcoal production and forestry are not included in the scope of the policy. Whilst the policy is not explicit in promoting the conversion of forests or woodlands to agriculture, it is implicit in its view that 440,000 km² of land in Tanzania “are suitable for agricultural production.” Similarly, the National Livestock Policy, (URT, 2006), includes 200,000 km² of “fallow and forestland” in its estimate of the national rangeland resource. Evidence that this assumes woodland conversion to agriculture is also reflected in the National Land Use Framework Plan for 2013–2033, which includes areas of woodland in the land categories designated for the expansion and intensification of agriculture (URT, 2013b).

As well as implicitly promoting land use change from woodland to agriculture, the National Agriculture Policy includes an objective to expand the area of agricultural land under irrigation from 0.4 to 7.1 million hectares (URT, 2013a). Expanding irrigation is presented as a strategy to mitigate climate change-related risks to agriculture. The dependence of agriculture on forest ecosystem services is recognized under cross-cutting issues and there is one policy statement, “*efficient use of renewable natural resources shall be strengthened.*”

Sustainable Charcoal Production and the National Land Policy

Tanzania has retained a land tenure structure that deliberately excludes the concept of “freehold” and is instead based on the principle that all land is public land where tenure is defined in terms of “rights of occupancy.” The National Land Policy of 1997 (URT, 1997b) identifies five important characteristics, including development conditions, that are imposed on landholders. The objectives of the policy include, “*Ensuring that land is put to its most productive use to promote rapid social and economic development of the country and protecting land resources from degradation for sustainable development.*” The policy is founded on a “use it or lose it” principle where rights of occupancy are tied to development conditions. This is important in the context of understanding the land policy–charcoal nexus since tenure is tied

to land use. However, the concept of “use” is not defined either to include, or exclude, sustainable forest management including charcoal production. In contrast, other uses are explicitly covered including agriculture, both for crop cultivation and livestock, mining, and settlements. There are no examples of rights of occupancy being given to private land owners for sustainable charcoal production from natural woodlands.

In 2015, the Tanzanian Government began a revision of the National Land Policy. The draft National Land Policy of 2016 (URT, 2016b) retains important elements of the 1997 policy, including the concept of rights of occupancy and the categorization of land as village, general, and reserved land. The draft policy does not mention sustainable charcoal production, although it does include an objective for the “*effective protection, conservation and sustainable utilization of environmentally sensitive areas*,” which are defined to include forests. The policy emphasizes formalization of land tenure including widespread issuing of granted and customary rights of occupancy. The promotion of the privatization of land tenure contrasts with the forest policy’s focus on communally-owned village land forest reserves.

Sustainable Charcoal Production and the National Water Policy

The water policy does not mention the term “charcoal,” and equates the term “energy” with electricity. The National Water Policy recognizes the forest–water linkages and states that, “*Forests have an important effect on the conservation of water resources.*” The policy goes on to state that with the current population growth rate, Tanzania will shift from having 2,700 m³/person/year to 1,200 m³/person/year between 2000/1 and 2025. According to UN criteria, this represents a transition toward water scarcity which is broadly defined as being 1,000 m³/person/year (Falkenmark et al., 2007).

DISCUSSION

The results of our analysis of Tanzanian policies on energy, forests, agriculture, land, and water, map out the marginalization of sustainable charcoal production across national policies despite the potential economic, social, and ecological benefits of managing natural woodlands sustainably for charcoal production. Our findings systematically document policy gaps related to sustainable charcoal production, and provide an in-depth and updated analysis of the broader policy environment.

The marginalization of charcoal is most starkly apparent in Tanzania’s energy policy, wherein the National Energy Policy 2015 (URT, 2015b) defines modern energy as the antonym to woodfuels, as the traditional energy carrier. The policy then deals exclusively with modern energy. This reflects a deep-rooted perception that charcoal is part of the traditional way of life that the national development vision seeks to transform, and has no place in the model of modernity envisaged for the country. The omission of a policy objective or statement on sustainable charcoal production from the National Energy Policy means that for the duration of this policy cycle, there is

no high-level commitment to produce charcoal and fuelwood more sustainably, nor to provide strategic oversight regarding its supply or quality. Given projected increases in demand for charcoal, and given that the majority of Tanzanians rely on woodfuel, this policy omission means that the National Energy Policy fails to provide guidance on Tanzania’s main energy carrier, a situation that risks perpetuating uncontrolled production and concomitant negative environmental impacts. Even if Tanzania’s draft biomass energy strategy were to be revived, in the absence of a policy-level objective on woodfuel, the strategy will have no anchor in national policy, thereby risking continued marginalization. This reinforces findings by Mwampamba et al. (2013) regarding the extent to which deeply rooted misconceptions about charcoal have led policy-makers to select policies that seek to exclude charcoal from the national energy mix, rather than embrace sustainable production techniques.

Economic development inevitably leads to trade-offs between land uses, and requires choices to be made between the conversion of forests into anthropogenic land uses such as agriculture, on the one hand, and maintaining natural forests with their inherent ecosystem services, on the other (Foley et al., 2005). Our review has shown how Tanzania’s development vision and sectoral policies have marginalized the sustainable woodland management land use option for village land. That agriculture is valued more highly than natural woodland, in part, reflects systemic challenges in integrating the complex concepts under-pinning ecosystem service valuation in decisions over allocation of land and natural resources (Martinez-Harms et al., 2015). Similarly the economic value of the charcoal trade, estimated at US\$ 650 million, is poorly understood and is not communicated in national accounts (Sander et al., 2013). For example, official national figures on government revenues from natural forest products do not distinguish charcoal from other products, including timber. Between 2011/12 and 2014/15, TFS reported TZS 187 billion (~US\$ 86.5 million) in natural forest product royalties (TFS, 2016), however, the proportion attributable to charcoal is not stated. Although national figures do not disaggregate revenues from charcoal, at a lower level of government, some TFS Zonal offices disaggregate their revenue by forest product. Zonal government revenue figures indicate that charcoal comprised between 10 and 71% of natural forest product revenues in some zones (TFCEG, 2015b, Lukumbuzya and Sianga, 2016). The absence of official figures on the value of the charcoal trade contributes to it being under-valued as a land use option, when compared with crops with well-documented trade data. Thus, whilst charcoal has many similarities with traditional crops, in terms of its requirements for land, labor, and net primary production, it is not considered a crop in the agriculture policy, and it is under-valued when land use tradeoffs are being made between agriculture and woodland on village land.

Similarly, sustainable charcoal production is not recognized explicitly as a land use in the National Land Policy. Given that land tenure is tied to land use in the Tanzanian land policy, the absence of explicit recognition for sustainable charcoal production as a land use category, risks the marginalization of sustainable woodland management in favor of agriculture and

other cited land uses, particularly given the current trend to privatize village land.

Optimizing water allocation between sectors is another relevant area for policy makers to consider, in the context of selecting an optimal mix of energy carriers, particularly given projected population increases. Beyond charcoal's dependence on forests and forests' absorption of water, traditional charcoal production places minimal demand on water supplies. In contrast, electricity generation from fossil fuels, as promoted in the National Energy Policy, 2015 (URT, 2015b), consumes water at all stages of the energy production life cycle (Mielke et al., 2010). As such, charcoal production using earth kilns is a more water-efficient energy source than electricity, a relevant consideration in the context of growing water scarcity. The relative water requirements of different energy carriers are not considered by either the national water policy, nor by the National Energy Policy.

Given the 2013 National Agriculture Policy's objective to increase land under irrigation, so the protection of the base flows essential for dry-season irrigation becomes critical for policy implementation. Sustainable woodland management for charcoal production may, therefore, be a useful policy tool for protecting base flows, when compared with conversion of woodland to agriculture in catchment areas. Policies that favor sustainable forest management and provide incentives to communities to safeguard the forest resources on their land, may therefore contribute to securing base flows vital to downstream water users, as well as reducing flooding risks.

Few attempts have been made to look strategically at the potential volume of charcoal production from current natural forests in Tanzania. CamCo Clean Energy (Tanzania) Limited (2014) calculated that 2.3 million tons of charcoal were consumed in Tanzania in 2012. They estimated that this required 350,000 ha of woodland, assuming a mean biomass of 50 m³/ha and a conversion efficiency of 19%. If we extrapolate this further and assume a 24 year rotation cycle for a sustainable system, it would require 8.4 million ha (24 × 350,000 ha) to be under management for sustainable charcoal production, in order to meet 2012 supply levels over the next 20 years or so. According to MNRT (2015) there are 21.6 million ha of forest on village land of which approximately 10%, or 2.3 million ha, are already included in areas under community-based forest management (CBFM). Of the existing areas under CBFM, a significant proportion is too ecologically sensitive to be appropriate for charcoal production, particularly given a tendency for CBFM projects to prioritize high biodiversity areas. Nonetheless, it shows that a significant proportion of charcoal demand could be met through sustainable production from the 21.6 million ha of woodland remaining on village land, including a portion of the area already under CBFM. Even meeting Tanzania's 5-year development plan target of reducing demand by 30%, would still require most of the remaining woodland on village land to be brought under sustainable production.

Given Tanzania's increasing, and increasingly urban, population, it is clear that sustainable charcoal production alone cannot meet projected urban energy needs. Undoubtedly fuel-switching is also needed. Including sustainable charcoal production in national policies would help to generate the

broad political support and stakeholder buy-in that is needed to transform the trade in favor of sustainable production.

The exclusion from national policies of sustainable charcoal production reflects three factors that affect each step in the policy cycle. These are the absence of detailed, accurate data on the charcoal trade; deeply-rooted negative perceptions of the trade; and the weak organizing and advocacy capacity of producers, traders, and consumers. The lack of reliable, current data about many important attributes of the charcoal value chain, as well as deeply held negative perceptions of charcoal amongst policy makers, have been highlighted by various authors (Mwampamba et al., 2013; Owen et al., 2013; Sander et al., 2013). Statements by some Ministers and other policy-makers in the current Government, as reported in the Tanzanian media and/or observed by the authors, generally reinforce the findings of Mwampamba et al. (2013). For example, the belief that charcoal is responsible for much of Tanzania's deforestation, is commonly cited by Ministers as the primary reason for excluding charcoal from Tanzania's energy mix^{1,2}. We propose three other reasons as to why policy makers choose to marginalize sustainable production. Firstly, few policy makers understand, or believe, that charcoal can be produced in a sustainable way. This reflects how few practical examples there are of charcoal being produced sustainably. Relatedly, technical expertise in managing natural woodlands for sustainable charcoal production is limited in Tanzania, where higher learning institutions have not embraced it into their curricula. Secondly, we contend that the role of agriculture as the main deforestation driver in Tanzania is poorly known amongst many policy-makers, in part, due to there being inadequate, and inadequately publicized, empirical research on deforestation drivers at a national scale. Given agriculture's primacy in Tanzania's economic development plans, we also speculate that it is politically convenient to apportion blame for deforestation on charcoal, instead of on agriculture. Thirdly, the difficulties of inter-sectoral coordination, required to transform the charcoal market, have hindered change. Undoubtedly, the political economy of the charcoal trade is complex and more in-depth research is needed to understand more fully the dynamics at play during the agenda-setting step of the policy cycle.

Advocacy from actors along the charcoal value chain has been muted in Tanzania. This reflects the informal nature of the sector where producers, transporters, and traders are often poorly educated, poor, and lack coordinating networks for advocacy. This contrasts with the advocacy capacity of stakeholders in the natural gas sector where natural gas prospecting and development companies had the resources, experience, and networks to lobby the Ministry of Energy and

¹On March 1, 2017, the Minister for Natural Resources and Tourism, Prof. Jumanne Magembe, banned transportation of charcoal from one district to another to combat what he described as deforestation in the country.' In Kitabu, G. How charcoal ban could work in the absence of viable alternative? The Guardian (Tanzania) 21/03/2017 P. 12. <http://www.ippmedia.com/en/features/how-charcoal-ban-could-work-absence-viable-alternative>

²Jumanne Maghembe, the minister of Tourism and Natural Resources, said in December that cutting wood for charcoal needs to stop because it spurs desertification. In Makoye, K. To save forests, Tanzania considers tax on charcoal. Reuters 23/01/2017. <http://www.reuters.com/article/tanzania-forest-charcoal-idUSL5N1F945L>

Minerals intensively during the formulation of the Natural Gas Policy and the National Energy Policy. Although some civil society organizations, including the Tanzania Forest Conservation Group, have facilitated meetings to highlight issues around charcoal production and to promote sustainable charcoal production, these efforts were insufficient to persuade the Tanzanian Government on the critical need for the 2015 National Energy Policy to provide direction for sustainable charcoal production (URT, 2015b). The weak voice of charcoal stakeholders has contributed to the National Energy Policy's exclusive focus on fossil fuels and electricity generation.

The review has identified important priorities for research including: quantitative assessments of the relative impact of drivers of deforestation and forest degradation; rigorous comparative studies of the costs and benefits of alternative energy carriers and policy options, taking into consideration inter-sectoral implications; experimentation with different models of sustainable charcoal production; and a strategic environmental assessment and cost-benefit analysis of the Government's tree planting proposals relative to increased investment in natural woodland management.

CONCLUSION

Sustainable charcoal production from natural woodlands has been marginalized as a policy option in all sectors in Tanzania. The marginalization of sustainable charcoal production in the energy and forest sectors is exacerbated by the land policy in providing no explicit recognition of sustainable woodland management as a recognized land use, and by the agricultural policy in promoting the expansion of agricultural land. If woodlands do not generate income for their owners, including communities, the economic rationale to convert woodland to agricultural land is strengthened. Assuming that sustainable charcoal production can incentivize sustainable woodland management, an opportunity is therefore being missed to embed a sustainable financing mechanism into participatory woodland management. Widespread conversion of woodland to agriculture inevitably undermines the ecosystem services generated by those woodlands, with corresponding risks to those sectors that depend on those ecosystem services, particularly agriculture. The marginalization of sustainable charcoal production from national policy is, therefore, a missed opportunity given the potential for it to contribute to more climate-resilient rural livelihoods, urban energy security, and sustainable management of woodlands with their inherent ecosystem services including climate change mitigation.

Based on this review we recommend that policy objectives and statements supporting sustainable charcoal be included in

REFERENCES

- Bailis, R., Drigo, R., Ghilardi, A., and Masera, O. (2015). The carbon footprint of traditional woodfuels. *Nat. Clim. Chang.* 5, 266–272. doi: 10.1038/nclimate2491
- Bradshaw, C. J. A., Sodhi, N. S., Peh, K. S.-H., and Brook, B. W. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Glob. Chang. Biol.* 13, 1–17. doi: 10.1111/j.1365-2486.2007.01446.x

the energy and forest sector policies whilst revising policies on water, agriculture, and land to include objectives and statements that promote sustainable natural forest management and reduce agriculture-driven deforestation. We envisage a charcoal market supplying charcoal from sustainably managed, community- and privately-owned woodlands to urban households. Tax revenues would continue to be retained at village and district level in order to incentivize and finance sustainable management of natural woodlands. The professionalism and organization of charcoal producers would increase with concomitant environmental benefits in terms of compliance with efficiency and sustainability guidelines, as well as improved livelihoods for producers, and other rural development gains.

The benefits of sustainable charcoal production become evident when viewed from the perspectives of multiple sectors. The nexus approach to policy analysis adopted in this paper highlights the need for policy makers to consider the inter-sectoral implications of charcoal production and to develop more robust mechanisms to value ecosystem services when making tradeoffs in the allocation of land and natural resources. The analysis also highlights the need for change throughout the policy cycle, including generating a stronger knowledge base, and valuing the needs and interests of more marginalized stakeholders, including woodland-owning communities and charcoal producers. The lessons learned from Tanzania have implications for other countries dependent on charcoal from natural woodlands including the leading charcoal producers in Africa, the Democratic Republic of Congo, Ethiopia, and Nigeria.

AUTHOR CONTRIBUTIONS

ND: lead author responsible for review concept, research design, drafting of the manuscript. CM: responsible for significant intellectual contributions to review design, inputs, and confirmation of manuscript for submission.

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- Brown, A. E., Zhang, L., McMahon, T. A., Western, A. W., and Vertessy, R. A. (2005). A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. *J. Hydrol.* 310, 28–61. doi: 10.1016/j.jhydrol.2004.12.010
- Bruijnzeel, J. (1988). (De)forestation and dry season flow in the tropics: a closer look. *J. Trop. Forest Sci.* 1, 229–243.

- CamCo Clean Energy (Tanzania) Limited (2014). *Tanzania Biomass Energy Strategy and Action Plan*. Africa-EU Renewable Energy Cooperation Programme.
- Chidumayo, E. N., and Gumbo, D. J. (2013). The environmental impacts of charcoal production in tropical ecosystems of the world: a synthesis. *Energy Sustain. Dev.* 17, 86–94. doi: 10.1016/j.esd.2012.07.004
- d'Agostino, A. L., Urpelainen, J., and Xu, A. (2015). Socio-economic determinants of charcoal expenditures in Tanzania: evidence from panel data. *Energy Econ.* 49, 472–481. doi: 10.1016/j.eneco.2015.03.007
- de Miranda, R. C., Sepp, C., Ceccon, E., Mann, S., and Singh, B. (2010). *Sustainable Production of Commercial Woodfuel: Lessons and Guidance from Two Strategies*. Washington, DC: The World Bank.
- de Wit, M., and Stankiewicz, J. (2006). Changes in surface water supply across Africa with predicted climate change. *Science* 311, 1917–1921. doi: 10.1126/science.1119929
- Falkenmark, M., Berntell, A., Jägerskog, A., Lundqvist, J., Matz, M., and Tropp, A. (2007). *On the Verge of a New Water Scarcity: A Call for Good Governance and Human Ingenuity*. SIWI Policy Brief. SIWI.
- FAO (2003). *Proceedings. Second Expert Meeting on Harmonizing Forest-related Definitions for Use by Various Stakeholders*. Rome: FAO.
- FAO (2004). *Unified Bioenergy Terminology*. Rome: Food and Agriculture Organization of the United Nations.
- FAO (2016). *FAOSTAT. Food and Agriculture Organization of the United Nations*. Rome: FAO. Available online at: <http://faostat.fao.org/default.aspx>
- Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., et al. (2005). Global consequences of land use. *Science* 309, 570–574. doi: 10.1126/science.1111772
- Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., et al. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proc. Natl. Acad. Sci. U.S.A.* 107, 16732–16737. doi: 10.1073/pnas.0910275107
- Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. (2013). High-resolution global maps of 21st-century forest cover change. *Science* 342, 850–853. doi: 10.1126/science.1244693
- Hosonuma, N., Herold, M., De Sy, V., De Fries, R. S., Brockhaus, M., Verchot, L., et al. (2012). An assessment of deforestation and forest degradation drivers in developing countries. *Environ. Res. Lett.* 7:4. doi: 10.1088/1748-9326/7/4/044009
- IEA (2014). *International Energy Association. Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa*. World Energy Outlook Special Report, 1–237.
- Jann, W., and Wegrich, K. (2007). “Theories of the policy cycle,” in *Handbook of Public Policy Analysis: Theory, Politics and Methods*, eds F. Fischer, G. J. Miller, and M. S. Sidney (Boca Raton, FL: CRC Press), 43–62.
- Jones, D., Ryan, C. M., and Fisher, J. (2016). Charcoal as a diversification strategy: the flexible role of charcoal production in the livelihoods of smallholders in central Mozambique. *Energy Sustain. Dev.* 32, 14–21. doi: 10.1016/j.esd.2016.02.009
- Krausmann, F., Erb, K.-H., Gingrich, S., Haberl, H., Bondeau, A., Gaube, V., et al. (2013). Global human appropriation of net primary production doubled in the 20th century. *Proc. Natl. Acad. Sci. U.S.A.* 110, 10324–10329. doi: 10.1073/pnas.1211349110
- Lukumbuzya, K., and Sianga, C. (2016). *Revisiting TRAFFIC's Recommendations to Improve Forest Governance in Tanzania*. Cambridge: TRAFFIC.
- Lund, H. G. (2015). *Definitions of Forest, Deforestation, Afforestation, and Reforestation*. Gainesville, VA: Forest Information Services. doi: 10.13140/RG.2.1.2364.9760
- Martinez-Harms, M. J., Bryan, B. A., Balvanera, P., Law, E. A., Rhodes, J. R., Possingham, H. P., et al. (2015). Making decisions for managing ecosystem services. *Biol. Conserv.* 184, 229–238. doi: 10.1016/j.biocon.2015.01.024
- Mielke, E., Anadon, L. D., and Narayanamurti, V. (2010). Water consumption of energy resource extraction, processing, and conversion, a review of the literature for estimates of water intensity of energy-resource extraction, processing to fuels, and conversion to electricity. *Energy Technology Innovation Policy Discussion Paper*, 2010–15. Harvard University.
- MNRT (2015). *Ministry of Natural Resources and Tourism. National forest Resources Monitoring and Assessment of Tanzania Mainland: Main Results*.
- Msuya, N., Masanja, E., and Temu, E. K. (2011). Environmental burden of charcoal production and use in Dar es Salaam, Tanzania. *J. Environ. Prot.* 2, 1364–1369. doi: 10.4236/jep.2011.210158
- Muhongo, S. (2016). “Natural resources and energy development and its contribution to transform Tanzania towards becoming a middle income country by 2025,” in *Presentation by the Minister for Energy and Minerals at the Annual Engineers Day, Mlimani City Conference*, Dar es Salaam.
- Mwampamba, T. H., Ghilardi, A., Sander, K., and Chaix, K. J. (2013). Dispelling common misconceptions to improve attitudes and policy outlook in developing countries. *Energy Sustain. Dev.* 17, 75–85. doi: 10.1016/j.esd.2013.01.001
- Ninan, K. N., and Inoue, M. (2013). Valuing forest ecosystem services: what we know and what we don't. *Ecol. Econ.* 93, 137–149. doi: 10.1016/j.ecolecon.2013.05.005
- Owen, M., van der Plas, A., and Sepp, S. (2013). Can there be energy policy in Sub-Saharan Africa without biomass? *Energy Sustain. Dev.* 17, 146–152. doi: 10.1016/j.esd.2012.10.005
- Price, K. (2011). Effects of watershed topography, soils, land use, and climate on baseflow hydrology in humid regions: a review. *Prog. Phys. Geogr.* 35, 465–492. doi: 10.1177/0309133311402714
- Ribot, J. C. (1999). A history of fear: imagining deforestation in the West African dryland forests. *Glob. Ecol. Biogeogr.* 8, 291–300. doi: 10.1046/j.1365-2699.1999.00146.x
- Sander, K., Gros, C., and Peter, C. (2013). Enabling reforms: analyzing the political economy of the charcoal sector in Tanzania. *Energy Sustain. Dev.* 17, 116–126. doi: 10.1016/j.esd.2012.11.005
- Schure, J., Ingram, V., Sakho Jimbira, M. S., Levangy, P., and Wiersum, K. F. (2013). Formalisation of charcoal value chains and livelihood outcomes in Central- and West Africa. *Energy Sustain. Dev.* 17, 95–105. doi: 10.1016/j.esd.2012.07.002
- TFCG (2015a). *Civil Society Organisation Comments on the Draft National Energy Policy 2015*. Tanzania Forest Conservation Group.
- TFCG (2015b). *An Analysis of the Ecological and Financial Sustainability of Natural Forest Management in Tanzania*. Tanzania Forest Conservation Group. TFCG Technical Paper 48, 1–49.
- TFS (2012). *Participatory Forest Management in Tanzania: Facts and Figures*. MNRT Department of Policy and Planning. Tanzania Forest Services Agency.
- TFS (2013a). *Guidelines for Harvesting in Village Land Forest Reserves*, 1–8. Tanzania Forest Services Agency, Dar es Salaam.
- TFS (2013b). *Tanzania Forest Services Agency Strategic Plan, July 2014–June 19*. Tanzania Forest Services Agency.
- TFS (2016). *Maelezo Kuhusu Wakala wa Huduma za Misitu, Tanzania: Majukumu, Mafanikio, Changamoto Na Mikakati (2011–2015)*. Ministry of Natural Resources and Tourism, Tanzania Forest Services Agency, 1–25.
- UN (2015). *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables*. United Nations (UN), Department of Economic and Social Affairs, Population Division. Working Paper No. ESA/P/WP.241.
- URT (1977). *The Constitution of the United Republic of Tanzania. Cap 2*. United Republic of Tanzania.
- URT (1997a). *National Environmental Policy*. United Republic of Tanzania.
- URT (1997b). *National Land Policy*. United Republic of Tanzania.
- URT (1998). *National Forest Policy*. United Republic of Tanzania.
- URT (1999). *The Tanzania Development Vision*. United Republic of Tanzania.
- URT (2002). *The Forest Act*. United Republic of Tanzania.
- URT (2003). *National Energy Policy*. United Republic of Tanzania.
- URT (2006). *National Livestock Policy*. United Republic of Tanzania.
- URT (2012). *National Climate Change Strategy*. United Republic of Tanzania.
- URT (2013a). *National Agriculture Policy*. United Republic of Tanzania.
- URT (2013b). *The National Land Use Framework Plan 2013–33*. United Republic of Tanzania.
- URT (2014). *National Forest Policy (Draft)*. United Republic of Tanzania.
- URT (2015a). *The Draft National Energy Policy*. United Republic of Tanzania.
- URT (2015b). *The National Energy Policy*. United Republic of Tanzania.
- URT (2016a). *The National Five Year Development Plan 2016/17–2020/21*. United Republic of Tanzania.
- URT (2016b). *National Land Policy (Draft)*. United Republic of Tanzania.
- URT (2016c). *National Environmental Policy (Draft)*. United Republic of Tanzania.
- Watkiss, P., Downing, T., Dyszynski, J., Pye, S., Savage, M., Goodwin, J., et al. (2011). *The Economics of Climate Change in the United Republic of*

- Tanzania. Report to Development Partners Group and the UK Department for International Development.
- Watson, R. T., Noble, I. R., Bolin, B., Ravindranath, N. H., Verardo, D. J., and Dokken, D. J. (2000). *Land Use, Land Use Change and Forestry*. Cambridge: Cambridge University Press.
- Willcock, S. L., Phillips, O. L., Platts, P. J., Swetnam, R. D., Balmford, A., Burgess, N. D. et al. (2016). Land cover change and carbon emissions over 100 years in an African biodiversity hotspot. *Glob. Change Biol.* 22, 2633–2956. doi: 10.1111/gcb.13218
- Woollen, E., Ryan, C., Baumert, S., Vollmer, F., Grundy, I., Fisher, J., et al. (2016). Charcoal production in the Mopane woodlands of Mozambique: what are the trade-offs with other ecosystem services? *Philos. Trans. R. Soc. B* 371:20150315. doi: 10.1098/rstb.2015.0315
- World Bank (2009). *Environmental Crisis or Sustainable Development Opportunity? Transforming the Charcoal Sector in Tanzania*. Policy Note. Environment and Natural Resources Unit for the Africa Region.
- Yanow, D. (2007). “Qualitative-interpretive methods in policy research,” in *Handbook of Public Policy Analysis: Theory, Politics, and Methods*, eds F. Fischer, G. J. Miller, and M. S. Sidne (Boca Raton, FL: CRC Press), 405–416.
- Zulu, L. C., and Richardson, R. B. (2013). Charcoal, livelihoods, and poverty reduction: evidence from sub-Saharan Africa. *Energy Sus. Dev.* 17, 127–137. doi: 10.1016/j.esd.2012.07.007

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