Global dry forests: a prologue

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SUMMARY

The dry forest biome covers extensive areas of the global tropics. However, the understanding of these forest formations from both human and biophysical perspectives varies widely both geographically and in terms of disciplinarity. While considerable resources have been made available for the sustainable management of the humid tropical forests, there has been a lack of comparable sustained attention on their dry forest equivalents. This special issue is an attempt to provide further insights into the state of the knowledge of global dry forests, and identify research gaps that could contribute to their long-term sustainability, both for human well-being and ecological integrity.

Keywords: global dry forests, food, energy, climate, biodiversity, livelihoods

Les forêts sèches de la planète: préface

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Le biome des forêts sèches représente d'importantes surfaces des régions tropicales. La compréhension de ces formations forestières dans une perspective tant biophysique que sociale varie toutefois beaucoup selon les régions et en terme disciplinaire. Alors que des ressources considérables ont été rendues disponibles pour une gestion durable des forêts tropicales humides, il n'y a pas un intérêt aussi soutenu pour les forêts sèches. Ce numéro spécial est une contribution pour approfondir l'état des connaissances sur les forêts sèches de la planète et identifier les lacunes en matière de recherche qui pourraient contribuer à leur durabilité sur le long terme, à la fois dans une perspective du bien-être humain et d'intégrité écologique.

El bosque seco en el mundo: prólogo

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El bioma del bosque seco cubre extensas áreas del trópico a nivel global. Sin embargo, la comprensión de estas formaciones forestales desde el punto de vista tanto humano como biofísico es muy variada tanto geográficamente como en términos de disciplinas. Mientras que se han

destinado considerables recursos a la gestión sostenible del bosque húmedo tropical, ha habido una falta de atención constante comparable sobre su equivalente del bosque seco. Esta edición especial intento ofrecer nuevas perspectivas sobre el estado del conocimiento sobre el bosque seco de todo el mundo e identificar vacios en la investigación que podrían contribuir a su sostenibilidad a largo plazo, tanto para el bienestar humano como para la integridad ecológica.

INTRODUCTION

Dry forests comprise slightly less than half of the world's sub-tropical and tropical forests. Despite their prevalence, tropical dry forests remain among the world's most threatened and least studied of the forested ecosystems, and, as such, may face greater threats than humid forests (Aide *et al*. 2013, Gillespie *et al*. 2012, Janzen 1988, Miles *et al*. 2006, Portillo-Quintero and Sánchez-Azofeifa 2010). Although a vast majority of research and development investment has focused on the humid forests of the tropics, dry forests once occupied a considerably larger area and up to a third of the global population lives in seasonally dry tropical areas (Miles *et al*. 2006). Yet dry forests have not attracted the same sustained international attention as humid tropical forests, despite having higher rates of deforestation (Shepherd *et al*. 2002). Perhaps as a consequence, the dry forest ecosystems face higher human development pressures than humid forests.

To date, there has been a notable lack of literature that examines dry forests from a global perspective, although some work identifying the extent of such forests has been undertaken (see FAO 2001, FAO 2012, Miles *et al*. 2006, Olson *et al*. 2001). The FAO, for example, has identified tropical dry forests as a Global Ecological Zone (GEZ), which includes the: "*….drier type of miombo and Sudanian woodlands, savannah (Africa), caatinga and chaco (South America) [and] dry deciduous dipterocarp forest and woodlands (Asia).*" (FAO 2000: 18). According to this classification, the largest expanses of dry forest occur in South America, sub-Saharan Africa (including Madagascar) and South Asia. Significant concentrations are also present through South-East Asia, northern Australia and parts of the Pacific, Central America and the Caribbean.

While there is general agreement within the literature that dry forests are under threat (see Gillespie *et al*. 2012, Kowero 2003), comprehensive data on the rates of deforestation and conversion of dry forests remain elusive, primarily because of the long history of forest clearance as human civilisation evolved, notably in India and the Americas. In the Americas, for example, Portillo-Quintero and Sánchez-Azofeifa (2010) show that two-thirds of tropical dry forest in the region has already been converted, and that in some countries the conversion rate is as high as 95%. Elsewhere, regional data are much harder to come by. This is primarily because the most reliable authoritative sources – such as the FAO Global Assessment of Forest Resources (FAO 2010) – do not differentiate between humid and dry forest types. However, it is estimated that up to 20% of the dry forest of Africa has been converted to agriculture (Timberlake *et al*. 2010), over 200,000 km^2 of forest has been lost in Latin America and the Caribbean (Aide *et al*. 2013) and that less than 10% of the dry forests of the Pacific islands remain (Gillespie *et al*. 2012). According to Miles *et al*. (2006), less than one third of the world's dry forest area lies within formal protected areas and thus, given the biodiversity and livelihood values of tropical dry forests, more efforts need to be targeted to their sustainable management.

DEFINING DRY FORESTS

There are a plethora of definitions currently available for the tropical dry forests. A widely accepted definition is that of the FAO that describes tropical dry forests as forests experiencing a "*tropical climate, with summer rains…a dry period of 5 to 8 months [and] annual rainfall ranges from 500 to 1500 mm*"[1]. Whatever definition is agreed upon, the current climate does not define the biogeography of tropical dry forests, particularly in the context of future unprecedented climate change. For example, if tropical climates become warmer and drier, understanding dry forests will be crucial – they may expand into areas that are currently dominated by humid forests. First, because of the open canopies, the dominance of grass communities and thus the increased proneness to fire, some areas considered dry forests under the FAO definition, such as the miombo in Africa and dry dipterocarp forests in Asia, might be more accurately described as savannah (e.g., Dexter *et al*. 2015, Lehmann *et al*. 2011). Underpinning different plant strategies to cope with the dry season, the degree of deciduousness in dry forest also varies from locality to locality (Apgaua *et al*. 2015, Bowman and Prior 2005). Finally, as Dexter *et al*. (2015) demonstrate, there are considerable floristic dissimilarities between dry forest formations on different continents. Therefore, there is still considerable scope for working toward a global and ecologically cohesive classificatory scheme for dry forests.

WHY ARE TROPICAL DRY FORESTS IMPORTANT?

This special issue is the culmination of a significant body of work related to the development of a strategy for engagement in dry forests (see Blackie *et al*. 2014, for a summary of the process). As such the aim of this publication is to highlight the value and importance of tropical dry forests throughout the tropics and to identify both geographic and thematic research gaps.

[1] http://www.fao.org/docrep/006/ad652e/ad652e07.htm

Food, diets and medicine

Dry forests contribute to local diets with wild fruits, vegetables/tubers, nuts, honey, edible insects, bushmeat, medicinal plants and other forms of direct provision. Such forest products are extremely important for local food security and dietary diversity, notably in times of agricultural scarcity (Rowland *et al*. 2015). The diverse diets provided by forest products also provide essential nutrients to otherwise vulnerable communities (Ickowitz *et al*. 2014). With agriculture being the major driver of deforestation, and with much of this occurring in drier regions of the world, dry forests and woodlands and the ecosystem services they provide, can be central to achieving broader food security objectives (Blackie *et al*. 2014). Unfortunately, however, Rowland *et al*. (2015) find that there have been very few studies that quantify the nutritional contributions of dry forests to diets; they call for research that combines rigorous nutritional methodologies with ecological knowledge to better understand these connections.

Energy

Wood and charcoal are the main source of energy for the majority of households in dry forested regions. Some 2.4 million people, around 40% of the population of less developed countries cook with wood-based energy sources. In dry forested regions, firewood and charcoal are currently the cheapest fuels compared with their alternatives: gas, oil, or electricity when not highly subsidized by the State. Most woodfuel supply chains are informal but nevertheless represent a major economic activity. The production, transport, and trading of woodfuel provides employment to many people despite the price of wood being relatively low and the resulting income from its sale being somewhat modest. However, the woodfuel supply chains require little initial technical skill or capital investment and such activities are more readily accessible for the poor and represent a safety net against poverty (Gazull and Gautier 2014). The safety net role of charcoal production for vulnerable households is one of the recent trends in the dry forest areas (Gumbo *et al*. 2013). In some areas, notably the miombo woodlands of Southern Africa, farmers are abandoning cultivation in favour of charcoal production (Malimbwi *et al*. 2000), which may have implications for future food security (Djoudi 2013). Despite the health risks of smoke inhalation (Wan *et al*. 2011), the use of wood energy to boil water also has important positive health implications through the reduction of water-borne disease prevalence (FAO 2014) as cooking food is important for killing pathogens. Using wood to cook food also is an indirect way to improve nutrition since many nutritious foods need to be cooked to make them fit for human consumption: grains, tubers, many leafy greens, and dried legumes all must be cooked to make them edible (Brouwer *et al*. 1997, Vira *et al*. 2014).

Livelihoods

Dry forests provide a wide variety of products that are gathered and sold (Djoudi *et al*. 2015). Such freely available products provide enterprise opportunities even for the very poor. With support, such opportunities can become a means of economic development and poverty alleviation. The African miombo alone is thought to support the livelihoods of over 100 million people in both urban and rural areas (Campbell *et al*. 2007, Djoudi *et al*. 2015, Syampungani *et al*. 2009). The differing role of males and females in the context of dry forest management for livelihood benefits are also important considerations for future research and development. Colfer *et al*. (2015) provide useful recommendations in this regard.

Carbon storage for climate change mitigation

Through the process of carbon storage, dry forests can help mitigate the processes associated with climate change (Becknell *et al.* 2012, Dexter *et al*. 2015). While it is recognised that dry forests store less carbon than humid forests, little is actually known about the actual amounts of carbon stored (although see Becknell *et al.* 2012, Day *et al*. 2014). Measuring carbon stocks in dry forests requires a different methodological approach from humid forests, and dry forest inventories are often incomplete or simply out of date. Efforts to measure carbon stocks need to be expanded from humid forests, where they are currently concentrated, into dry forests. Long term ecological monitoring of dry forests will ultimately allow key questions to be addressed such as the amount of carbon that could be stored if the huge expanses of degraded dry forest in Latin America were allowed to regenerate, which has been estimated to be significant (see Portillo-Quintero *et al*. 2014).

Climate change adaptation

Dry forests are highly resistant to drought (Pulla *et al*. 2015). The food and livelihoods provided by dry forests play a critical role in building the adaptive capacity of communities living in their proximity in the context of threats of climate change. Even though the role of dry forests differs according to wealth, there is growing evidence that dry forest ecosystem services help reduce sensitivity and increase adaptive capacity of the poorest households and communities. These households rely on provisioning services to cope with drought crises by extracting wild food, by selling forest and tree products and by providing fodder that protects livestock assets (Brockhaus *et al*. 2013, Fisher *et al*. 2010, Pramova *et al*. 2012, Shackleton *et al*. 2007). Regulation services of forest also reduce the sensitivity of agriculture to droughts (Pramova *et al*. 2012).

Most studies on climate change adaptation focuses on community and livelihoods aspects. One missing literature body in the climate change adaptation arena is the climate change impact on the composition, biodiversity and the ecological health of dry forest ecosystems. The possible impacts of climate change on the dry forest are important since they will affect also the adaptive capacity of people in the future.

Support for agriculture

Dry forests provide a wide range of ecosystem services, such as water management, livestock provisioning, pollination

services, nutrient cycling and soil improvement (Foli *et al*. 2014). While these processes are not fully understood, they play important and complex roles in supporting the agricultural systems (within and adjacent to these forests) upon which millions of subsistence farmers depend.

Biodiversity

Dry forests harbour considerable biodiversity in terms of species richness, endemism and functional diversity of plants and animals that sometimes even exceeds that of humid forests (e.g. Medina 1995, Murphy and Lugo 1995). Biodiversity, in turn, has been extensively valued in terms of both tangible and intangible benefits to humans (e.g. Edwards and Abivardi 1998). Apart from aforementioned direct benefits that have environmental or economic value, dry forests are also important for the recreational, aesthetic and cultural value they provide.

RESEARCH GAPS AND OPPORTUNITIES

The overwhelming majority of the literature on tropical dry forests regarding food security, livelihoods and community forestry focuses on the miombo woodlands of southern Africa, and this is particularly true of the literature regarding food security, livelihoods and community forestry. Latin America is increasingly well studied, particularly with regards to carbon, Payment for Environmental Services (PES), community forestry, novel conservation approaches (such as sustainable intensification for land sparing) and deforestation.

Priorities for future research should include addressing this imbalance and standardising our state-of-knowledge by improving the geographical coverage of research on deforestation for example. Meanwhile, additional research is needed to investigate human-forest interactions (beyond agriculture-forest frontier dynamics) in Latin America, Asia, the Caribbean and the Pacific. Information on the gender dimension is available in Africa and South Asia, but needs further attention globally, particularly in Latin America. The role of dry forests in food security is of particular interest (see Rowland *et al*. 2015).

The impacts of cross-border and internal trade and investment, potential for carbon sequestration, and environment-development trade-offs are under-researched in all regions and would benefit from evenly distributed research. Finally, research into how the needs and demands of both humans and forestry systems change as societies change should be considered a priority. This would include, for example, how the demands of forest management change with levels of poverty, equity, urbanisation, climate change, etc. For dry forests this is particularly relevant, as many of these forest formations are located in regions where environments and societies are undergoing rapid transitions.

Latin America

Latin American dry forests have possibly the strongest biophysical research base of all the regions, with a significant numbers of studies documenting biophysical aspects, such as species population changes and carbon storage (Portillo-Quintero *et al.* 2014, Sánchez-Azofeifa *et al*. 2010, see also Apgaua *et al*. 2015). This is also the region with the most robust deforestation data, based on the extensive use of remote sensing technologies. The region is probably the best studied in terms of PES and carbon storage, with Mexico in particular the subject of considerable research (Cairns *et al*. 2003, Kerr *et al*. 2014). Livelihoods and community forestry have also been extensively studied (e.g. Baldauf *et al*. 2015), though with little specific attention to gender.

However, the role of dry forests in the direct provision of food and in nutrition is not well documented in the region, aside from a few ethnobotanical studies with indigenous peoples. Latin American research tends to focus more on how humans affect the forest, and thus there is a lack of research into how people utilise the forest aside from clearing it for agriculture (see Stoner and Sánchez-Azofeifa 2009). There is also need for greater research into forest users and uses, small-scale forest enterprises, climate change adaptation and the management of production forests in Latin America.

The *Caatinga* forest region of Brazil is one of the largest and most species-rich dry forest formations in Latin America but it is frequently considered to be shrub-land rather than forest (see Apgaua *et al*., Dexter *et al*. both 2015). This issue – which is also commonly encountered in the African miombo (Miles *et al*. 2006) – suggests that the *Caatinga* may be often be excluded from relevant research and reporting, such as with forest clearance figures.

In the Caribbean, food security, livelihoods, and community forestry remains almost totally un-researched despite the existence of several biophysical studies (for example, Gonzalez and Zak 1994, Murphy and Lugo 1995). Although a number of gender studies exist for this region, in general they do not specify forest quality; interestingly, much of this literature has emphasized masculinities (e.g. Crichlow *et al*. 2014) in contrast to most gender material available globally that has focussed primarily on women alone (Sunderland *et al*. 2014). Mapping and cataloguing the biophysical characteristics of these forests should be a high priority in the first instance.

Africa

African dry forests, and particularly the miombo, have been extensively studied for decades (Campbell 1996, Chidumayo and Gumbo 2010). As such the region has by far the greatest body of research on livelihoods, food security, community management and conservation/development trade-offs. Small-scale enterprises and the impact of larger-scale trade and investment are also better researched in African dry forests than elsewhere, as is an understanding of the governance systems (see Gautier *et al*. 2015). While adaptation literature exists for the African dry forests, the body of research on carbon storage, REDD and ecosystem services is limited but quickly expanding.

There is substantial research into the biophysical aspects of African dry forests, but reliable deforestation data are scarce and there is the opportunity to improve this perhaps,

by following the Latin American example of extensive remote sensing[2]. Research into the sustainable management of production forests in Africa is also scarce. Although CIFOR and partners have led significant research efforts into adaptation to climate change in African dry forests, the geographical focus has tended to be confined to several West and Central African countries. The miombo forests of East and Southern Africa are poorly served by adaptation research and might be a particular priority given the numbers of people reliant on these forests.

Beyond a few biophysical studies (Timberlake *et al*. 2010) and studies on the timber trade (FAEF 2013) and investigations of illegal logging (MacKenzie 2006, EIA 2013), the dry forests of Mozambique are less well studied. Angolan dry forests are even less well studied, despite being found extensively in that country. Similarly, the dry forests of Madagascar have received relatively little global attention and the extensive summary provided in this Special Issue (Waeber *et al*. 2015) will no doubt inform future research and development initiatives there.

Asia

Asian dry forests (defined here as comprising the dry forests of Indochina as well as those of the Lesser Sundas and Central and Peninsular India) are less well studied, despite being abundant in the region. For example, Poffenberger (2000) suggests that up to 30% of forests in mainland Southeast Asia are dry forest and Waeber *et al*. (2012) state that up to 60% of Indian forests are comprised of dry forests. Although the FAO initiated an Asian dry forests initiative in the early 2000s, little activity is apparent over the last decade and several important dry forest countries (such as Laos and Cambodia) are not members (Appanah *et al*. 2003, FAO 2008).

India is probably the best studied, with some biophysical (e.g. Pulla *et al*. 2015, Sagar *et al*. 2003), community forestry and livelihoods research available, although in low quantities. Livelihoods studies tend to have a narrow focus on non-timber forest products and small enterprises, and little is known about the role of direct provisioning (for example see Mahapatra and Tewari 2005, Narendran *et al*. 2001, Waeber *et al*. 2012). Research into community forestry although well-developed, tends to include other forest types meaning that dry-forest specific conclusions are not given. This is also true of gender studies, which are quite abundant for India.

The dry forests of Thailand have also been subject to some research, mostly regarding floristic composition and human-induced changes in Thai dry forests (Bunyavejchewin 1983, Ghazoul 2002, Johnson 2002) as well as a narrow but very valuable collection of studies related to food utilisation and the forest (see Moreno-Black and Price 1993, Moreno-Black *et al*. 1996, Price 1997, Setalaphruk and Price 2007, Somnasang and Moreno-Black 2000).

Elsewhere, dry forest specific research is virtually non-existent, although the region's dry forests do sometimes feature in studies that cover several different forest types.

Australia and the Pacific

Within Australia, there is little consensus on what constitutes dry forest, and this itself is an issue deserving of further research. Under the broad bioclimatic definition used in this paper, Australian dry forest could potentially involve many of the vegetation types that have traditionally been called "vine-thickets" or "dry rainforest" (Webb 1959) and other fire-sensitive non-eucalypt vegetation. In addition, if miombo woodlands are included as "dry forests" in Africa, then the structurally similar and similarly fire maintained Australian *Eucalyptus* woodlands also need to be included. These vegetation types across tropical northern Australia are relatively well studied in terms of floristic composition and fine scale mapping of extent are available (Sattler and Williams 1999). It appears that virtually nothing is known about the dry forests of the Pacific Islands, aside from one or two studies into their floristic composition and conservation status and several archaeological studies into the history of the forest (see Blackmore and Vitousek 2000, Gillespie and Jaffré 2003, Pau *et al*. 2009, Gillespie *et al*. 2012). At the very least, the mapping and cataloguing of the biophysical characteristics of these forests should be a high priority. The IUCN initiated a programme focused on the dry forests of New Caledonia in the early 2000s, but little progress appears to have been made and the most recent activity dates back to 2002 (PFS 2004, IUCN 2012). The human dimension is also lacking in the literature.

SUMMARY

Despite the fact that there is a significant amount of research available regarding dry forests and their value to people across the world, dry forests remain under-researched and under-prioritised in national and international policy. An analysis of the state-of-knowledge on tropical dry forests (Blackie *et al*. 2014), supplemented by the papers in this Special Issue, suggest the following research priorities be implemented in order to generate knowledge to inform global, regional and national policy processes:

- Implement national and global inventories of tropical dry forests, both for floristic and biogeographical assessment, but also for an estimate of carbon stock, carbon balance, tree growth, and tree mortality.
- Work towards a more ecologically cohesive global classification and definition of tropical dry forests.
- Update information on deforestation and degradation rates across all regions.

[2] Although deforestation data is available, most figures tend not to distinguish between forest types. Another challenge in remote sensing to assess dry forests states is the inability to distinguish between degraded and non-degraded forests, as for example shown in Madagascar (see Moat and Smith 2007).

- Improve knowledge of the biophysical aspects of dry forests, their ecosystem services and opportunities for sustainable intensification of agriculture and conservation agriculture in Africa, Madagascar, Asia, the Caribbean and the Pacific.
- Improve knowledge and quantitative modelling of dry-forest dynamics based on paleoecological and long-term monitoring studies to help predict dry forest responses to disturbances, management regimes and future climate change.
- Further investigate human-forest interactions in Madagascar, Latin-America, the Caribbean and the Pacific, including attention to gender differentiation and trends.
- Focus more attention on products and spaces that interest women, and assess migration and population issues related to gender.
- Marry the knowledge held within the field of scientific forestry with the perceptions, knowledge and practices of local communities.
- Facilitate information sharing on research methods and approaches across all dry forested regions and between various stakeholder groups (e.g., direct users and decision makers).
- Further investigate the contribution of the components of tropical dry forests to food security/sovereignty and dietary diversity.
- Take in account the floristic values of each tropical region in future tropical dry forest conservation and agricultural strategies.
- Further investigate the relationship between biodiversity and ecological resilience in tropical dry forests.
- In all tropical dry forest regions, increase research and understanding of the sustainable management of dry forests and undertake an analysis of forestry and other policy arenas that affect them.

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