



The forest restoration frontier

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Abstract Forest restoration has resulted in approximately 300 million ha of restored forests until today. During the second decade of the twenty-first century several international initiatives have sprung up which aim to add 350 million ha of restored forest by 2030. The paper reviews the development of the forest restoration frontier. It tracks trends of the increase of restored forests, emphasizing developments since the second half of the last century. It equally reviews past and ongoing policies, programs, and projects to restore forests. Available data show how the area of restored forests has progressively increased since the 1960s. There are three major objectives to restoring forest: (1) to produce forest products (timber and other products) or spaces for recreation, (2) to produce regulatory ecosystem services (sequestered carbon, erosion control) and (3) to achieve improvement of rural livelihoods. The emphasis on each of these objectives has changed over time and each objective implied different policies and arrangements, involvement of actors and use of technology and know-how. The large international programs and projects since the beginning of the twenty-first century promote forest restoration for biodiversity conservation, regulatory ecosystem services and improving wellbeing of resident populations. Some of the findings related to the development of the forest restoration frontier since the mid-twentieth century suggest that some of the ambitious goals may be unrealistic and result in unwanted outcomes.

Keywords Biodiversity · Community forestry · Ecosystem services · Forest products · Land cover change · Plantations

INTRODUCTION

Forest restoration is of interest because the global community recognized the dependence of people on ecosystem services, including those from forests (MA 2005; IPBES 2018). Deforestation and forest degradation undermine the provision of ecosystem services that originate from forests, or forest ecosystem services, and these are main causes of biodiversity loss. Because of the ecosystem services that forests provide and the biodiversity they contain, it is now widely acknowledged that forest restoration can contribute to goals pursued by sustainable development actors and international initiatives. For instance, forests contribute to food and water security, boost rural employment, and protect biodiversity (SOFO 2018). Forests are an important terrestrial carbon repository and sink and forest restoration is considered able to capture atmospheric CO₂ and reduce the greenhouse gas effect (Bastin et al. 2019). Forest conservation and forest restoration are key strategies to achieve the UNFCCC Paris Agreement as well as SDG 13 (Climate Action) and SDG 15 (Life on Earth).

Forest restoration refers to bringing back forest where it has disappeared or restoring the conditions of forests to how they were before degradation had occurred. Other terms that have been used with similar meanings are forest rehabilitation, reforestation, and afforestation (e.g. de Jong 2016). Forest rehabilitation refers to efforts that result in tree cover establishment on formerly forested grasslands, brushlands, scrublands or barren areas (Chokkalingam et al. 2005). Reforestation usually refers to restoring a tree cover on land where forest had existed before. Afforestation refers to the establishment of a tree cover on land

where there has not been a forest before for a certain timespan. Forest landscape restoration is a relatively new term used by many forestry specialists and organizations, sustainable development professionals and even climate change communities. IUCN defines it as the “ongoing process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes” (<https://bit.ly/2WGtFl6>).

This paper aims to provide a brief overview of how the forest restoration frontier has evolved in recent times. It responds to the following questions: (1) How have ‘restored forest’ increased in area over time, but especially since the mid-twentieth century? (2) How was forest restoration undertaken during different periods in the forest restoration history, by whom and for which purposes? (3) What have been consecutive or concurring international and related national policies and programs, and what are the motivations for forest restoration?

A frontier perspective on forest restoration

We use the concept of frontier as a framework of our analysis. Forest restoration constitutes a progressively expanding physical area of land that is subjected to forest restoration. Referring to this as an expanding forest restoration frontier represents a use of the concept similar to its use as the ‘forest frontier’ or ‘deforestation frontier’. Forest frontier and deforestation frontier refer to the progressive expansion of mostly agricultural land into forest areas and the unavoidable conversion of those forests (e.g. Maartens et al. 2006; Friant et al. 2019). This meaning of frontier concurs with its definition as “the edge of land where people have settled and built towns, beyond which the country is wild and unknown” (Online Oxford Dictionary, n.d.). This also represents the meaning of frontier that was popularized by Turner’s (1893) to analyse the move of European settlers in the USA into land until then occupied only by Native Americans.

The term frontier has meanwhile been used to represent the expansion of other intellectual constructs, including science, and public debates and opinion (e.g. Rowe 2011; Bush 2020; Alexander 2021). The forest restoration frontier can be understood to contain those dimensions. For instance, we argue that there has been a progressive expansion of the forest restoration knowledge frontier. Undertaking a search in Scopus using the terms ‘forest restoration’ demonstrates an exponential increase in publications that are captured with such a search, of less than 10 publications per year until 1987 to 1528 publications in 2020 alone. While of interest, we will in this paper not address the expansion of forest restoration related knowledge.

A third dimension of the forest restoration frontier is its increased prominence in the debates and public statements (discourses) of forestry professionals and forest stakeholders, as well as the increase in international and national public policy and administration actions to foster forest restoration. References to forest restoration, to promote it, to express an opinion about it related to the interests of a particular audience, or for other reasons, have increased dramatically since the 1990s. We corroborated this also with searches in Scopus using the key word ‘forest restoration’ together with ‘policies’ (4 documents in 1999, 151 documents in 2020), ‘communities’ (6 documents in 1995, 393 documents in 2020), or ‘biodiversity’ (4 documents in 1996, 282 documents in 2020). These results indicate that forest restoration is also discussed in research papers that link it to either policy processes, rural development goals or efforts, and biodiversity conservation discussions.

The paper is structured as follows. “Methods” section describes the methods used to obtain information and data to answer the questions of the paper. “The expansion of planted and naturally regenerated forests” section analyses the physical expansion of restored forests, both planted forests and naturally regenerating forests, since the mid-twentieth century, but emphasizing especially trends of the last 30 years. “Forest restoration projects and programs” section explores how this can be connected to actual international and national efforts to undertake forest restoration, including by looking at restoration policies, programs, and implementation. “Contemporary forest restoration discourses and global programs” section reviews more recent policies and programs related to forest restoration, and links those to what are contemporary forest restoration discourses. “A transition of forest restoration” section reflects on the evidence of the previous sections to recognize a forest restoration transition, of how forest restoration objectives have changed over the years and how this has affected forest restoration policies and practices. “Forest restoration in a time of big projects” section reviews several large international initiatives that promote forest restoration and what implication this might have for trends recognized based on historical evidence. “Conclusions” section concludes and points at limitations of the study.

METHODS

This paper is primarily based on information and data from published sources. We also draw on more than 20 years of research on forest restoration or related topics (Smith et al. 1996; Chokkalingam et al. 2005; de Jong et al. 2006, 2017). In previous work on forest restoration (e.g. de

Jong 2010), we recognized a number of historical periods in which forest restoration had unique features different from other periods. We were aware of colonial forest restoration in Southeast Asia (e.g. Peluso 1991; de Jong 2010) and of forest restoration during the Edo era Japan (Totman 1984). We were also familiar with early and mid-second half twentieth century forest restoration in various other locations in the world, and the so called ‘fuel wood crisis’ debate (Deweese 1989), which was an important incentive for development cooperation support for forest restoration among rural communities (Wiersum 1999). We also were familiar with the development of the forest restoration debate since the 1990s (i.e. de Jong et al. 2001, 2006; de Jong 2010).

Based on this recognized historical development of forest restoration, we undertook focused literature searches, in Scopus, Google Scholar and Google, to find papers, reports or any other information on forest restoration that appeared relevant for the questions we tried to answer. The searches included, for instance, ‘colonial forest restoration’, ‘forest restoration Japan’, ‘forest restoration China’, ‘fuelwood crisis’, and multiple others. In each search we varied key words to assure that we captured a maximum number of documents.

While undertaking these searches, we screened the results and selected only documents that appeared to provide relevant information. During the searches and subsequent consultation of documents we noted information and data that added to the understanding of the characteristics of forest restoration during different periods and which helped to answer the papers questions. But we also carefully looked for information that challenged our assumption of differences between historical periods. Based on this procedure, for instance, we came to recognize that forest restoration to generate regulating ecosystem services already was an important part of considerations since the early 1970s and onwards (Wiersum 1999; Park and Youn 2017), something that we had not been aware of before starting the research.

THE EXPANSION OF PLANTED AND NATURALLY REGENERATED FORESTS

The term forest is a controversial concept. FAO defines it as an area of at least 0.5 ha with trees at least 5 m high and a percentage area cover of at least 10%, or trees that will in time reach these criteria (GFRA 2015). Stakeholders whose primary interest is conservation of species and natural habitats prefer a narrower definition of forest than foresters whose primary interest is the production of timber (Chazdon et al. 2016). We use the Global Forest Resource Assessment (GFRA 2015) definition, as we rely on

statistics and reports which define forests similarly to the FAO definition. Data are available in the GFRA statistics, but also from other sources (e.g. Hansen et al. 2013; Song et al. 2018). These statistics, however, are not without their challenges (e.g. Pearce 2018).

Over the last 50 years much attention has been given to deforestation. Deforestation of tropical forests became widely discussed among forest scientists but was also of wider public interest since the 1980s, since when FAO began to produce its regular updates on the state of the world’s forest. Deforestation appeared to be severe and accelerating (e.g. Allen and Barnes 1985), it was linked to multiple indirect causes (e.g. Rudel 1989), and it had important implications not only in locations where deforestation was taking place (e.g. Houghton 1990).

The 2005 FAO GFRA for the first time reported a decline of the high annual rates of deforestation since the 1980s and 1990s, from 7.27 million ha/year during 1990–2000 to 4.58 million ha/year during 2000–2005. The 2020 GFRA revised these numbers and reports a reduction in net annual forest decline from 7.8 million ha during 1990–2000, to 5.2 million ha during 2000–2010 and to 4.2 million ha during the 2010–2020 years (GFRA 2020). Over the period 1990–2020, the regions Central America, South America, Eastern and Southern Africa, North Africa, and West Africa, as well as South and Southeast Asia recorded regional net forest decline (GFRA 2020). The regions East Asia, Western and Central Asia, Europe, and Caribbean had net increase in forest area. Relevant countries with net forest increase include China, India, Philippines, and Vietnam, among others.

The numbers of the previous paragraph hide an unprecedented increase in the area of planted forests during 1990–2020. FAO (1996) provides an estimate of total area of planted forests of between 62 million ha and 92 million in 1963. The wide range being a result of uncertainty of planted forest in China. The 1990–2020 period saw an increase in planted forest of 123 million ha, from 170 million ha in 1990 to 293 million ha in 2020 (GFRA 2020). This represents an annual increase of over 4 million ha of planted forest. During the same period, however, a total area of 420 million ha of natural forest was lost (GFRA 2020).

Somewhat counterintuitive the largest gains of planted forest did happen in South America and South and Southeast Asia, in addition to East Asia (Fig. 1). In 2020, the three regions with the largest area of planted forest, much of which was planted long before 1990, included East Asia (98 million ha), Europe (74 million ha) and North America (46 million ha). The fourth and fifth region in this list are Southern and Southeast Asia (31 million ha) and South America (20 million ha), both regions with the highest net deforestation until today. All other sub-regions

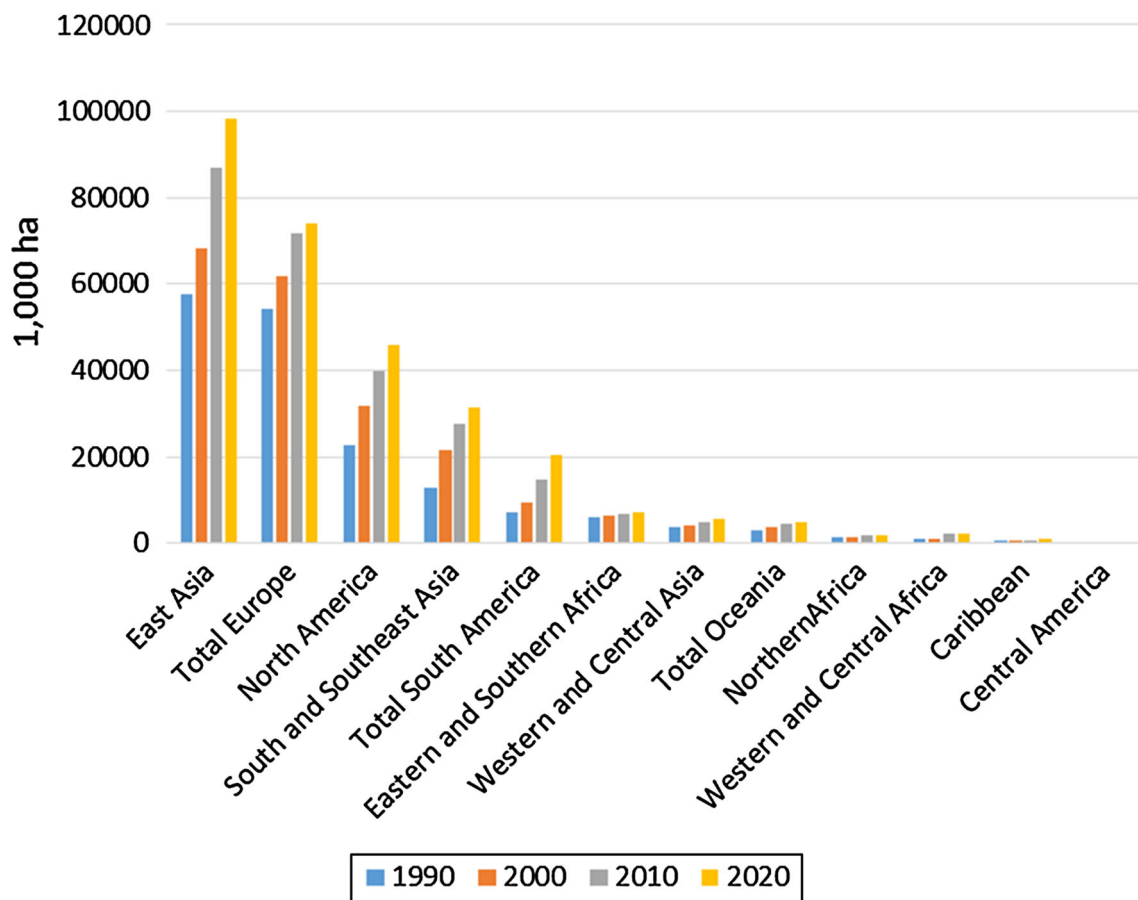


Fig. 1 Increase in planted forests in the world's regions (data from GFRA 2020)

in the GFRA statistics showed significant increase in planted forests (GFRA 2020, Fig. 1).

Natural forest regeneration

Planted forests are a result of active forest restoration efforts. However, forest restoration can also take place because of natural regeneration. When forests grow back naturally it also represents restored forest. However, it is less evident if data on naturally regenerating forest in various GFRA reports represent forest restoration as defined in this paper. The latest GFRA (2020) only provides data on naturally regenerated forests, which the report also refers to as natural forest. Where this category of forest evidently has contributed to the expansion of the forest restoration frontier is when there is in a particular country a net increase over time in the category naturally regenerating forests, and this constitutes forest restoration.

GFRA (2015) estimates that between 2010 and 2015 the world lost annually an area of 8.8 million ha of naturally regenerating forest, but that during the same period, an area of 2.2 million ha of such forest was restored. Reviewing the

data, there are 33 countries within the GFRA 2020 statistics that demonstrate a sustained increase in the category naturally regenerating forests over the 1990–2020 period. Of these, 13 are European countries, including Azerbaijan. Europe demonstrated a net increase in its area of naturally regenerating forest between 1990 and 2020. Some 14 countries experienced an increase in naturally regenerating forest between 2010 and 2020, but not for the 1990–2020 period (GFRA 2020). This means, however, that between 2010 and 2020, 47 countries experienced an increase in their naturally regenerating forest area.

FOREST RESTORATION PROJECTS AND PROGRAMS

The increase in planted forests and naturally regenerating forests tells only one part of the story of the development of the restoration frontier. Equally relevant is understanding the efforts undertaken to bring about forest restoration. Or, in other words, when, where and why was forest restoration actively pursued, how was it done, by whom, and what

have been the outcomes? Forest restoration efforts have a long history and changed dramatically over the years. The great diversity in these efforts makes it more difficult to provide a succinct overview of past, recent and contemporary forest restoration efforts, and link those to the outcomes presented in the previous section.

Pre-modern and early modern forest restoration

Historical accounts of ancient tree planting are from India and China. Stone engravings from 2000 years ago report wide-scale tree planting ordered by King Ashoka who reigned over what is nowadays India and neighboring territories (Rahman 1993). Emperors of the Chou Dynasty established a forest service to protect forests and restore denuded lands (Evans 2009). These ancient tree planting efforts have not left any noticeable marks on modern forest cover. This is different with early modern forest restoration efforts, many of which were initiated in the nineteenth century, but some already as early as the thirteenth century. Many of those have left their imprint on the forest estates of multiple countries (Evans 2009). Wide scale forest planting was reported in England, Germany and France since the sixteenth, seventeenth, and eighteenth century (Evans 2009), but also in China since the twelfth century (Huang and Lan 1988) and in Japan since the eighteenth century (Totman 1984).

European countries, including France and Scotland, but also Sweden, Germany and Poland experienced net forest cover increase since the nineteenth century. For instance, in the Netherlands agriculture, grazing and forest product collection had depleted forest cover to only 2% at the beginning of the nineteenth century. Since then, forest restoration has brought back 10% of forest cover today (Mohren and Vodde 2006). Forest restoration in the Netherlands was initially a private actors' affair, but later government job creation programs became a major factor in the country's forest restoration. Scott's pine (*Pinus sylvestris*) was planted on poor sandy soils in most forest restoration projects, and until 1970 half of Dutch forests were pine forests. Similar processes have taken place in other European countries, where since the nineteenth century forest restoration of denuded lands with non-indigenous pine species, larch, and spruce became common. The nineteenth century's forest restoration efforts across Europe have influenced profoundly the European forest landscape until today (Evans 2009; Oosthoek and Holtz 2018).

Colonial and post-WW II forest restoration

Forest restoration became an important component of colonial forestry of European colonial powers like Great Britain, Netherlands, Germany, and France. A significant

expansion of planted forests in colonial territories occurred during the late nineteenth century. The sultans of Java already planted teak (*Tectona grandis*) forest during the fifteenth century, but once the Dutch took control of Indonesia, they also took over teak production and trade. British foresters planted teak forests in Myanmar and India since the mid-nineteenth century (Evans 2009) and in India sal (*Shorea robusta*) was also widely planted. In South Africa and New Zealand, wide-scale forest restoration mainly with pine species began in the early twentieth century (Evans 2009).

Colonial foresters promoted rational forestry or 'scientific' forestry, relying on forestry methods brought over from home. European forestry during the nineteenth and long into the twentieth century had as one of its main paradigms the optimization of timber production, which was pursued by managing even aged stands that were planted and harvested following a rotational sequence. European foresters used these models when they became in charge of forestry in India, Java or South Africa (e.g. Bennet and Kruger 2015). European foresters had been advocating continuous forest cover silviculture, already since the nineteenth century (e.g. Schabel and Palmer 1999), but we are not aware if that became part of colonial forestry.

The forest plantation practices created a legacy that changed little until mid-twentieth century. Major shifts in forest restoration policies and programs only started since the 1970s (e.g. Wiersum 1999; Gilmour 2005). Until that date, countries that had been former colonies planted mostly single species forests (Gilmour 2005), as commercial enterprises, but also because such plantations were expected to be necessary to meet forest product needs of a growing population with more purchasing power (Arnold 1999). Indeed, forestry production became an important part of national forest policies, and this implied the planting of forests with the main purpose of wood production (Evans 2009). South Africa, Brazil and India expanded their planted forests areas during those years, again relying mostly on non-native species. The mid-twentieth century forest restoration was to produce timber or veneer, and to a lesser extent pulpwood and wood chips (Evans 2009). China and India also turned to forest restoration to address desertification, soil erosion and to manage water drainage and the protection of farmlands (e.g. Ren et al. 2012).

Forest restoration for socio-economic development

The 1970s saw a shift in development theory and practice towards a greater emphasis on agriculture, mobilizing the rural sector, and meeting the basic needs of the rural poor. Similar trends developed in forestry. The 1972 World Forestry Congress held in Buenos Aires had as a central

theme: Forests and socio-economic development (Westoby 1979). This was followed by the congress 5 years later in Jakarta with the theme: Forests for people. These thematic foci of the two congresses represent forestry ideological changes that had profound impact on forest restoration thinking and practice. Following WW II, international development cooperation supported forest production in low-income countries, but largely emphasizing industrial production. Since the 1970s, forestry development cooperation began to expand focus on tree planting to benefit local communities and smallholders. The result of this was eventually that around 1980 about 40% of the newly added planted forests were for non-industrial purposes (FAO 1988).

The 1970s and onward saw forest restoration projects carried out by ODA agencies, including FAO, the World Bank, and the World Food Program (de Jong et al. 2006) in overseas localities aimed to produce fuelwood, fodder, construction materials, some of which was to be traded in markets, food, medicine and herbs in woodlots or other communal forests (Evans 2009). One major trait of socio-economic development-oriented forest restoration focused on solving a looming fuelwood crisis, which was perceived to be happening in the global south. Recognition of the importance of wood fuels as the principal source of domestic energy, because of the increased attention given to the energy sector following the 1973 rise in fossil fuel prices, highlighted the role of forests in meeting such needs. As a result, major efforts were expanded since the 1970s and onward to encourage communities to plant trees. These efforts had as a goal to avoid the looming fuelwood crisis, but also to address desertification and soil erosion, and to increase rural incomes (Arnold 1992; Gilmour 2005).

Next to pursuing rural development objectives the 1970s community-based forest restoration addressed local environmental challenges, for instance soil erosion. For example, during the 1970s the South Korean government encouraged villages to create collective woodlots to stop destructive use of hill forests that were protecting downstream agricultural lands. Organizations like for instance mothers' clubs that had family planning as their main purpose became important contributors to forest restoration in South Korea during that time (Kincaid 1972), which eventually led to South Korea's forest transition (Park and Youn 2017). Hill community forestry in Nepal similarly had its origins in increasing concern about deforestation of watershed areas. The social forestry program in India had its origins in a 1976 report of the National Commission of Agriculture, which recommended encouraging people to grow trees on their village and farmlands to reduce the pressures on production forests caused by mounting rural demands for fuel and other forest products, and forest

grazing. Other comparable initiatives in the same period included the village forestry program in Thailand, in forest areas heavily encroached by people seeking land to cultivate, and the village afforestation initiative in Tanzania (Wiersum 1999).

The fuelwood crises did not pan out as was predicted because, as Dewees (1989) argued, local livelihood and resource use strategies of those who depended on fuelwood were profoundly misunderstood. This, however, did not diminish the interest among essentially the same actors to continue to include forestry collaboration within ODA agendas. The focus of the latter, however, changed since the late 1980s on supporting communal natural forest management, with the dual goals to generate local livelihood improvements, but also to conserve forests to assure the provision of especially regulatory ecosystem services of much interest to non-local beneficiaries (Pokorny and de Jong 2015).

Turn of the century forest restoration

The global forest restoration frontier since the 1990s and onwards is a complex picture. At about 1990, there were an estimated 100 million ha of industrial plantations, of which only 25 million were fast growing species. This implies there existed close to 75 million ha of planted forests with slow growing species (Sedjo 1999), and an almost equal area of planted forest of different categories. These consisted of both native and non-native species, according to the 2015 FRA data (Payn et al. 2015). In 2000, an estimated 22% of the planted forest were planted to fast growing species (Evans 2009). The GFRA (2020) estimates suggest that in 2020 131 million ha of the area of planted forests were actual commercial forest plantations and 44% of those, or 58 million ha, were planted to non-native species. A considerable proportion of those can be categorized as long rotational forests. The proportion of planted forests with native species and with non-native species varies considerably per continent. North American planted forests are 98% native species and South American planted forests are about 98% non-native species.

The increase in planted forests is the result of thousands of largely national efforts, many carried out with either ODA support or international loans, or with national funding only (e.g. de Jong et al. 2006). Contributing was also the enthusiasm to address forest cover and condition, following the United Nations Conference on the Environment and Development (UNCED). UNCED produced the Forest Principles, which were embraced by many countries. The post UNCED efforts to restore forests during the latter years of the twentieth century have been reviewed by Chokkalingam et al. (2005) and de Jong (2010). The overarching insights from these studies are that countries

adopted their own strategies to undertake forest restoration. National governments planned their own schemes, but also engaged progressively more actors, including lower tiers of governments, civil society organizations and communities, but also individual households and the private sector. Prominent examples of nationally driven forest restoration are from China, India, the Philippines, and Vietnam, four countries that increased their net forest cover resulting from forest restoration, but also reducing conversion of natural forests (de Jong 2010; de Jong et al. 2017).

A comparison between these four countries suggests that large scale projects initiated and financed by the state, in particular central government, characterizes forest restoration in China. State controlled initiatives but involvement with local communities and the private sector characterized forest restoration in Vietnam. In both India and the Philippines forest restoration resulted from diversified government programs and support, but also was an outcome of private and other social actors engaging in forest restoration outside these programs. Contrasting with these examples, are for instance forest restoration efforts in countries like Brazil and Peru. These two countries caught up later with pursuing, but also embracing strategies to engage local land users, local governments, and national civil society actors (de Jong 2010).

CONTEMPORARY FOREST RESTORATION DISCOURSES AND GLOBAL PROGRAMS

Forest restoration planning and practice have had their unique discourses, like other forestry domains (e.g. Medina et al. 2008; Arts and Buizer 2009; Leopold 2014; Katila et al. 2017). Those became more prominent following the shift since the 1970s in attitudes towards forest restoration claiming to pursue socio-economic development and environmental improvement. Two major shifts in forest restoration discourses have concurred with the emergence of a suit of multi-national initiatives to achieve ambitious global forest restoration targets.

The first shift argues for restoration of more biodiverse, structurally complex forests, as opposed to restoration of single species forests. This can be called the ‘ecological forest restoration’ discourse. OTA (1983) long ago pointed at the benefits of multispecies forest restoration and the urgency to consider both conservation and a wider spectrum of forest ecosystem services in forest restoration. A key publication that argued for a broadening of forest restoration goals and methods is the 1994 Lamb paper: ‘Forest rehabilitation in the Asia–Pacific region: past lessons and present uncertainties.’ In this paper a well-articulated point is made for multiple objectives, using locally adapted species, restoring diverse forests that provide a

wider range of goods and services and contribute to local development. The shift in the discourse is reflected in the use of the terminology. Until 1987 the term forest restoration was not used in the academic literature, whereas the term reforestation already appeared commonly in publications since the 1960s. Through much of the 1990s and early 2000s, many forestry specialists used the term forest rehabilitation, which emphasizes restoring a narrower functionality of producing specific goods or services, whereas forest restoration implied restoring forests towards structural and biodiverse forests (Mansourian et al. 2005; Lamb et al. 2006; FAO 2017). An additional manifestation of the ecological forest restoration discourse is the appearance of advocacy groups that actively campaign against single species forest plantations (e.g. Carrera and Lohman 1996; Friends of the Earth 2010).

The second shift in forest restoration discourse is the forest landscape restoration discourse. In a paper from 2003, Maginnis and Jackson (2003) argue for the case of forest landscape restoration. The term forest landscape has been used among forest professionals and academics and used to be understood as an extensive area of land covered with forest. Since about a decade and a half, and inspired by the definition from IUCN, forest landscape restoration has gained a new understanding as combining ecological restoration with pursuing local socio-economic improvements (<https://bit.ly/2WGtFl6>). This ideological change in the forest restoration discourse combines both ecological and socio-economic goals of forest restoration within a single concept, but also advocates expanding forest restoration on agricultural lands contiguous to forestlands, lands that implicitly are considered to be degraded. The recent international forest restoration initiatives with ambitious goals to restore forests on vast areas of lands across the globe have embraced the two discourses, and especially the forest landscape restoration discourse (e.g. Reinecke and Mareike 2018).

The earliest example of a new generation of internationally coordinated efforts to restore forests within multiple countries and with defined areal restoration targets are the APECs Forest Cover Goals, formulated in 2007. This initiative called for the restoration of 20 million ha of forest by 2020. Next, the Bonn Challenge, which originates from 2011 sought to restore 150 million ha of degraded forest lands by 2020 and 350 million ha by 2030 (Mansourian and Kleine 2013). The Bonn Challenges adheres to considering forest restoration as defined by IUCN. The New York Declaration on Forests endorsed the Bonn Challenge, but also called for commitments of countries and private sector actors to end deforestation in international cattle, soybean and oil palm supply chains (e.g. Wolosin 2014). The United Nation Strategic Plan for Forests (<https://bit.ly/3cs49Hb>) has formulated similar ambitious forest

restoration targets. Regional initiatives include Initiative 20 × 20 which expects to restore 20 million ha of forests in Latin America and the Caribbean, and the African Forest Landscape Restoration Initiative which aims to restore 100 million ha in Africa by 2030 (Humphreys et al. 2019).

Under these multiple global and regional initiatives, multilateral and non-governmental organizations, national as well as sub-national governments, civil society organizations and private sector actors have made pledges and initiated efforts to contribute to the restoration of millions of ha of deforested and degraded lands (Chazdon et al. 2015; IUCN 2015). The justifications for the various international initiatives also broadened, and include provisioning multiple regulatory ecosystem services, including storing carbon, but also to contribute to the socio-economic improvement of rural livelihoods. These initiatives are motivated by assessments that an estimated 2 thousand million ha degraded or deforested forestlands can be restored (Minnemeyer et al. 2011), or that planting 900 million ha of tree cover globally could capture 200 Gt of carbon out of the atmosphere and store it in trees, to bring back atmospheric carbon to pre-industrial levels (Bastin et al. 2019).

The APEC 2020 Forest Cover Goals is a case of internationally coordinated efforts to restore forests of interest, because it reached its completion year in 2020. A review of its performance might provide indication of what can be expected of other more recent initiatives with a 2030 horizon. The initiative was endorsed by all 21 APEC member countries. Until 2015, 77% of the targets were achieved. By 2020, planted forest is expected to have increased by 31.3 million ha within all APEC countries, but old growth natural forest and other natural regenerated forests were expected to have declined by 1.4 million ha and 4 million ha, respectively (APFNet 2015). Of the net 25 million ha of forest to have increased within the APEC countries until 2020, 19.9 million will be located in East Asia, 4.3 million ha in the Americas, 3.4 million ha in Russia and 0.4 million ha in the Pacific. Net forest cover, however, is expected to decrease by 3.5 million ha in Southeast Asia (APFNet 2015).

China is by far the major contributor to achieving the 2020 Forest Cover Goals, not the least, because forest restoration has been a long-lasting goal in China (Ren et al. 2012). The country now is also engaged in an ecological restoration of first generation restored forest, much of which was planted during the 1990s and onward largely as single species forests (Hua et al. 2017; Wang and Meng 2018). Upon its completion the APEC 2020 Forest Cover Goals will have achieved the target it set out to achieve, but important areas of old growth structurally diverse and biodiverse forests have been replaced with much less structurally diverse or biodiverse planted forests. In

addition, the total forest estate in the APEC member countries will have increased in the more northern countries but decreased in its tropical member countries.

A TRANSITION OF FOREST RESTORATION

Forest restoration includes responding to a broad spectrum of needs for forest ecosystem services, which has resulted in a diversification of forest restoration practices (Bauhus et al. 2010). There are three major objectives for which forest restoration has been pursued: (1) the production of specific forest commodities, in most cases timber or other wood products (Sedjo 1999). (2) To achieve environmental benefits, i.e. for the regulatory ecosystem services that forest provide (e.g. Dai et al. 2017), but also to create forests for their scenic beauty and as places for leisure and recreation (Ramsay and Taylor 2018). And (3) to contribute to livelihood improvements of groups who suffer reduced benefits caused by forest loss or forest degradation, or whose livelihoods might improve from forest restoration (Ashraf et al. 2015; Nguyen et al. 2015).

Over the years the relative importance of these three major objectives has changed (Table 1). Before the 1970s most of forest restoration focused on producing forest commodities. Generating regulatory ecosystem services (e.g. control of erosion and desertification) was a second objective but this objective became much more prominent in later years. It has, for instance, been the number one driver of the major increase in forest restoration in China since the 1990s (Ren et al. 2012). As mentioned above, since the 1970s the forest sector recognized the importance of forests in rural people's livelihoods and the third objective, contribute to improving livelihoods, became an important motive for forest restoration efforts including as part of international development cooperation (e.g. Arnold and Dewees 1995).

It might be obvious that the three different objectives result in different practices, arrangements and actors involved (Table 1). Where forest commodity production is the primary objective, traditional silviculture practices and know-how are employed by a range of actors, including corporations, smaller companies, but also smallholders who grow one or a few ha of trees to sell the wood in local markets (e.g. Grebner et al. 2013). When forest restoration is undertaken for the sake of producing regulating ecosystem services, the actors involved are different. Governments or government agencies are major actors in this kind of forest restoration, as they restore forests on behalf of multiple beneficiaries (Bauhus et al. 2010; Baral et al. 2016). Civil society actors and private sector actors do engage in forest restoration to achieve protection objectives, for instance when companies depend on

Table 1 Overview of restoration era and relevant attributes

Period	Locations	Main protagonists	Paradigm/narrative	Implementation
Early modern	Europe, China, Japan others	National actors, private and government	Forest goods and services for economic elite, or autonomous self-regulating communities	Feudal arrangements, private restoration, government schemes
Colonial	Colonial territories of European countries	Colonial government forestry specialists and forestry agencies, coerced local labor	Modernization of local 'backward' resource management practices. Increasing colonial profits	Colonial forestry agencies defining proceedings. Local rulers and people engaged in implementation
Post-WW II	Former colonial territories Countries receiving ODA support	National governments and agencies oftentimes supported by ODA actors	Contribution to national economic development, avoid rural scarcity and improve livelihoods, address environmental impacts	National programs implemented by government agencies with financial and technical ODA support
Late twentieth century–early twenty-first century	Multiple countries with negative deforestation impacts	National governments and agencies, ODA actors, NGOs and BINGOs; expansion of commercial private sector plantation forestry	Production forestry, rural development forestry, provisioning of regulatory services	Dominance of national programs still with external but declining ODA support; private sector plantation production
Early twenty-first century	Countries with deforestation degraded lands	National actors (governments, civil society, private sector integrated into international initiatives)	Providing wide range of regulatory services, contributing to rural economic development, expanding commercial production	Coordinated international initiatives to which national actors make commitments and then implement on their own

watersheds to yield a tradable service, they may engage in forest restoration to assure that the service is not threatened. This may happen in the case that private actors exploit a hydropower installation and forest restoration is undertaken to reduce erosion into the water basin of the installation (e.g. de Jong et al. 2006).

The third objective of forest restoration, improving rural livelihoods, is the perhaps most complex objective of the three discussed here. The outside actors who try to engage rural dwellers to pursue forest restoration objectives are in many cases quite similar in different locations. An external agent engages with communities to plant smaller areas of trees, and the principal goal of this is to either produce forest products to be used by the community, as in the case of fuelwood projects in the 1970s (Deweese 1989), or to produce a commodity that can be sold in local or regional markets to increase the financial income of the communities involved (Köhlin and Amacher 2005; Hoch et al. 2012; Ashraf et al. 2015). The primarily facilitating external agent commonly coordinates and collaborates with other agencies and private sector actors to set up and organize a supply chain for the commodity that is being produced by the community, in which case increasing financial income is the primary objective.

While during the early years of forest restoration to support communities, the production of goods like fuelwood for local use was the primary goal (Gilmour 2005), in subsequent years forest restoration that involved communities has mainly focused on producing goods that are to be

traded in local or non-local markets (Arnold and Dewees 1995; Hoch et al. 2012). In addition, where nowadays community-based forest restoration is pursued, as a rule improving local livelihoods is only one of the objectives, and it is combined with the generation of regulatory ecosystem services.

An important, but not the only, example of the combination of those two objectives in community forest restoration are Clean Development Mechanism (CDM) projects. Efforts to achieve local livelihood improvements through forest restoration projects, with or without a complementary goal of generating regulatory ecosystem services, have had mixed success (e.g. Hoch et al. 2012; Ba et al. 2020; Hultman et al. 2020). Not uncommon is that community tree planting projects are initiated, but that maintenance of plantations does not continue after the project cycle is completed (Hoch et al. 2012). Quite commonly this is a result of the tree plantation not yielding sufficient benefits (Chokkalingam et al. 2005; Hoch et al. 2012). There are, however, examples of successful community forest restoration projects that have resulted in sustained forest restoration (e.g. Truong et al. 2017; Hernández-Aguilar et al. 2020) and community benefits (van der Meer Simo 2020).

An analysis of the forest restoration frontier development requires choices on the exact meaning of forest and restoration. These choices have implications for how the analysis locates and interprets data and information, among others. In this paper we relied heavily on the term 'planted

forest’ as it is used by FAO and the statistics that the GFRA produces every 5 years (GFRA 2015, 2020). Over the last 60 years or so, a large proportion of forests that have been planted are forests to produce one commodity, timber, wood chips, or pulp. Most of the planted forest in 2020 were of native species (GFRA 2020). Many of these forests do produce additional forest ecosystem services, including water regulation and influencing weather patterns (Bauhus et al. 2012; Baral et al. 2016). They provide habitat for plant and animal species that would not have been present without the forest on the same location. Planted forests provide places for recreation and contribute to scenic landscapes. One can make the argument that short rotation industrial tree plantations, of acacia, eucalyptus, or pine species should not be recognized as forests, when a review is being made of the development of the forest restoration frontier (Friends of the Earth 2010). The GFRA (2015, 2020) include short rotation tree plantations in the statistics of planted forests, because they fall within the definition of forests that FAO uses.

There is an additional important argument in this debate. Even where the objective of restoring forest is to create structurally diverse and biodiverse forests, with a more complex ecology and presumably a wider suit of ecosystem services, these efforts start with planting one or possibly a few species. The major differences between planted production forests and planted structural and biodiverse forests become apparent only after a certain number of years. In a vast number of incidences, even where forests were planted for soil protection services, watershed regulation or other similar regulatory ecosystem services, often the planting has occurred as single species plantation, and in many instances after a largely single tree species forest had grown, efforts have been made to increase the species diversity in those forests. This has happened, for instance, in China, where huge areas of forests were planted from the 1990s onwards and only later it was recognized that it is necessary to increase tree diversity of those forests to make sure they can provide the required ecosystem services (e.g. Wang and Meng 2018). Large areas of forests of Europe have gone through a similar process, and this forest transformation has shaped much of the European forest landscape of today (EEA 2015). Ecological restoration is considered an important management strategy in large areas of European forests today (Halme et al. 2013).

FOREST RESTORATION IN A TIME OF BIG PROJECTS

The evidence provided in the different sections of this paper allow some reflection on possible near future trends of the development of the forest restoration frontier. The

trends that we suggest below are based on our own expert judgement, our understanding of the forest restoration frontier past developments, and using deductive reasoning. As explained in “Forest restoration projects and programs” section of the paper, a suite of ambitious international programs has sprung up and many actors have made commitments to contribute to their goals. If the Bonn Challenge is being met, then between now and 2030 an additional 200 million ha of forests will have been restored, or more as not all the 150 million ha that were targeted by 2020 have yet materialized. While these calculations sound promising, some of the findings of this paper do suggest that caution is advised with assuming that by 2030 the global area of restored forests will have increased with the targeted 350 million ha. This also holds true for the lofty goals of enhancing ecological functionality and improving human well-being across deforested and degraded areas.

The trends over the last 15 years suggest that caution is required in predicting how much forest can possibly be restored over the next 10 years. The pace of planted forest increase has declined between 2005 and 2015, compared to the 1990–2005 period (Payn et al. 2015). The Bonn Challenge has not been able to increase the global area of restored forest with 150 million ha by 2020, as expected. The success of the APEC 2020 Forest Cover Goals can for a large part be attributed to individual countries that already were undertaking wide-scale domestic forest restoration when the goals were agreed upon (de Jong 2016). They also have resulted in a de facto replacement of old growth forest with planted forest and is relocating the total APEC forest estate to its northern member countries. The experiences of that program do not imply that subsequent programs will be unequivocally successful.

Forest restoration to be completed under the Bonn Challenge or related initiatives favor the restoration of structural and biodiverse forests, which is more costly and takes more time. This means that with the same amount of effort and resources the rate of forest restoration will slow down. The implications are that if the ambitious targets are expected to be met, they will require more effort and more resources. The second complicating factor is that increasingly national governments are diverting responsibilities for forest restoration to lower tiers of government, but also in the prevailing discourses communities are presented as major beneficiaries but also active participants of forest restoration (e.g. Erbaugh and Oldekop 2018). In response to this, many international and national operating organizations are trying to engage communities in tree planting projects. The impact of these projects on communities is hard to foresee, and to what extent they result in restored forests is also a question that begs answers (Chokkalingam et al. 2005).

In the prevailing discourses there is a great role assigned to communities to be stewards of forest restoration (or forest landscape restoration), and when this happens, communities are expected to benefit from their active involvement (Erbaugh and Oldekop 2018; Erbaugh et al. 2020). There is reason to question whether if communities will universally benefit from forest restoration projects initiated by external agents (e.g. Malkamäki et al. 2018; Ba et al. 2020; Hultman 2020). The sweeping claims that forest restoration projects to be implemented under the Bonn Challenge and other concurring programs will benefit communities is not a given. National and subnational governments have signed up for these programs and they feel obliged to fulfill their commitments. At least some reports on forest restoration undertaken between government agencies and communities (e.g. FORIG 2016) do not differ substantially from the sorts of projects reviewed by Ba et al. (2020) and Hultman et al. (2020). Ba et al. (2020), for instance, describe coercive engagement of local dwellers in forest restoration projects in China. A plausible scenario is that a significant proportion of the thousands of projects that will be undertaken over the next decade with the involvement of communities to meet the Bonn Challenge will be tree planting projects guided by implementing agencies which may follow engagement procedures with communities that funding agencies approve of, but where communities have little true decision-making input (e.g. Evans et al. 2014). The projects will be attractive to communities because they receive payments for their participation, but once the projects have ended, the benefits will dry up (e.g. Hoch et al. 2009, 2012). In that sense, the forest landscape restoration discourse does appear a reinvention of previous discourse that claimed to engage communities in efforts to preserve or restore forests, for their own benefits and for distant forest beneficiaries of regulatory ecosystem services (Dove 1994). The forest restoration to address the fuelwood crisis (Deweese 1989), but also the non-timber forest products discourse of the 1990s (Dove 1991) and the community forestry discourse of the 1990s and 2000s (Pokorny and de Jong 2015) have been recognized as primarily motivated by non-local perceptions of problems and possible solutions.

CONCLUSIONS

Forest restoration is one of several terms that have been used to represent efforts to bring back forests where there were none, but where they had been before. The use of this term does suggest that the restored forest is a forest somewhere on the continuum of single species planted forest and structural and biodiverse forest that has a closer resemblance to old growth natural forest. If one accepts

prevailing forest definitions, most of planted forests that nowadays exist in the world are part of the global restored forest estate. Relying on several sources that estimate planted forest change over time, but especially the 2020 GFRA, the paper portrays the increase of restored forest during the last 60 years, including 293 million ha of planted forests worldwide in 2020. The purpose of forest restoration has evolved over the years. Forest restoration is undertaken to produce goods, i.e. timber and others products, to generate regulatory ecosystem services (carbon storage, erosion control), but also as part of rural development efforts in low-income regions. In many forest restoration efforts where this last goal is pursued nowadays, it is combined with the second goal, the generation of regulatory ecosystem services demanded largely by non-local forest users. Since the second decade of the twenty-first century forest restoration has gained increased international attention. Ambitious forest restoration goals have been formulated, to be achieved by 2030, including restoring ecosystem functionality and improving the well-being of the resident population in locations where forest restoration is considered feasible. Evidence included in this paper suggests that some of these goals are not realistic, and if they are pursued at all costs, unwanted outcomes are to be expected. A major gap in the forest frontier development knowledge relates to linking efforts to restore forests, through programs and projects, and the outcomes of these efforts, and this constitutes an important area for future research.

Limitation of the study

We believe that with the methods used we gained a good overview of the literature, academic and otherwise, in which aspects of forest restoration are being discussed. Our intention was not to provide a systematic overview of the forest restoration literature, but to undertake a characterization of what have been past and present trends in restored forests and forest restoration efforts, and what were the stated goals and objectives and who endorsed those. We only referred to sources insofar as necessary to elaborate our argument, and ultimately used only a small portion (99 references) of all the material that we consulted. We fully recognize that in the paper we present our own view of the expansion of the forest restoration frontier, along with its multiple dimensions. But we believe this to be a well-informed view. An analysis like this undertaken by others might have proposed a different development of the forest restoration frontier in its multiple dimensions or may have emphasized others. However, the analysis of the paper is based on a solid understanding of the relevant literature, which we interpreted based on our own personal views.

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