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Great Green Walls: Hype, Myth, and Science

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Abstract

Visions of planting walls of trees to block the expansion of the desert have long been promoted but never realized. The green wall myth persists today even though it is premised on outdated understandings of desertification. We review the history of the idea of green walls and focus on two sets of contemporary initiatives to assess their outcomes: peri-Saharan programs (Algeria's Green Dam and Great Green Wall in sub-Saharan Africa) and China's Three Norths Shelterbelt Program. This review reveals a mixed record of technical success with low rates of the establishment of monocultures of fast-growing trees vulnerable to disease. While there is evidence for reduced wind erosion in some areas, afforestation is also associated with reduced soil moisture and lowering of water tables. Social impacts include increased water scarcity for people and livestock in some cases, and resource enclosures that particularly work against pastoralist livelihoods.

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1. INTRODUCTION

Green walls refer to continuous bands of planted trees stretching across single or multiple countries in dryland regions. As socioecological projects, green walls invoke powerfully attractive images of maintaining life over the assumed sterility of the desert through human ingenuity and effort. A wall of planted trees is envisioned to hold back an expansionary desert from degrading the productivity of the lands behind the wall. Despite the persistent discursive power of this image, its scientific foundation rests on now discredited understandings of desertification.[1] Desertification, scientifically understood as land degradation due to human mismanagement, is less a regional phenomenon across a broad front than a highly localized phenomenon in areas of greater and more persistent human pressures. The power of the green wall vision is illustrated by its persistent use in promotions of a diverse array of dryland afforestation initiatives with different afforestation patterns (e.g., shelterbelts, scattered woodlots and larger afforested blocks, and agroforestry) and goals (ecological rehabilitation, carbon sequestration, and improved climate resilience). In short, green wall rhetoric mobilizes support and empowers certain actors rather than describing actual dryland afforestation practices.[2] This article focuses on the vision, practices, and effects of these programs.

This review was written during a period of global enthusiasm for trees and mobilization for mass afforestation, with the World Economic Forum's Trillion Trees initiative the most prominent example (**https://www.1t.org/**) but also a wide range of other afforestation efforts across the globe (3). While the arborocentrism of this moment has a long history (see below), concerns about climate change and an interest in increasing the sequestration of industrial carbon has led to a rapid rise of tree planting initiatives. The world's drylands could be seen as "empty" and thus important "untapped" landscapes to store carbon. Through a consideration of the empirical record

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[1] Today, the scientific community (e.g., 1) distinguishes two general causes behind the loss of dryland vegetative cover: desertification (land degradation due to human land uses) and desiccation (climate-induced vegetative loss). Both are associated with interannual changes that can be seen as greening and browning of dryland patches, but the latter (desiccation) is much more likely behind oscillations of desert extent at the regional level (2).

[2] What connects the disparate programs reviewed here is that their proponents have actively or passively invoked the green wall metaphor to describe the overall goal of their afforestation efforts. Passive promotion of the green wall imaginary includes the continued use or acceptance of the green wall label for programs that deviate strongly from its meaning. In short, green wall language has less to do with the reality of afforestation in arid lands and more to do with the marketing of these efforts to donors, government officials, and a broader public.

of green wall programs, this article outlines reasons to be cautious. Trees are often not suited for the arid zones where they are planted and, even if they are established, may have negative ecological and social impacts (4). By ignoring the need for ecological and social monitoring of afforestation impacts, green wall enthusiasm has often worked to hide the mixed record of these initiatives.

GGWI: Great Green Wall Initiative

TNSP: Three Norths Shelterbelt Program

Green wall and other mass afforestation programs are also sociopolitical programs—seeking not only to ecologically transform broad landscapes but also to shape societies and economies. Green wall areas can be seen as hinterlands to state control with limited investment, poverty, and a lack of communication and transportation infrastructure. They are often inhabited by ethnic minorities and politically marginalized people. The large-scale planting of trees has always been an act of territorialization—a way of creating state space and asserting control over nature and people. More specifically, large-scale afforestation projects are an example of what Vandergeest & Peluso (5) have called internal territorialization, practices within the constructed boundaries of the territorial state that extend power over people through demarcating boundaries and designating land use types. Any assessment of green wall programs must not ignore the political interests behind them and their effects on rural communities.

This review first provides a brief summary of the history of the ideas of desertification, afforestation, and most particularly green walls in arid lands. This provides important context for a focused review of the technical success as well as ecological and social outcomes of contemporary green wall programs. We focus on the two regions that have attracted the largest and most ambitious green wall programs in the world today: the area bordering the Sahara Desert [Great Green Wall Initiative (GGWI) and Algeria's Green Dam programs] and northern China [China's Three Norths Shelterbelt Program (TNSP)]. After descriptions of their organization, institutional histories, and afforestation techniques, we present a synthesis of their experiences in two thematic sections that address their ecological and social impacts. The article concludes with lessons learned from this review.

2. HISTORY OF GREEN WALLS

An infatuation with trees as a panacea for environmental problems and for controlling difficult populations has been widespread for longer than most realize. For nearly 250 years, the ideas of desiccation theory (that deforestation causes aridification and that planting trees will attract rainfall, tempering drought) and of deserts as threatening wastelands have combined to lead to substantial tree planting programs in many parts of the world, especially in arid and semiarid zones. Infused with these ideas, by the early nineteenth century, arborocentrism, a tree-centric worldview, had developed among Anglo-European thinkers, and dryland areas came to be widely understood not as natural landscapes but as degraded by human actions, including livestock grazing (6).

The French were the earliest to develop desiccation theory and the first to apply it to the drylands, within a few years of occupying Algeria in 1830. It is here that the false idea of the spreading desert originated and was used to facilitate colonial goals, especially land appropriation. Although the term desertification was not coined until 1927, the processes believed to cause it were well-described early in the French colonial occupation of Algeria. It is also in colonial Algeria that the origins of the idea of shelterbelts of trees to protect against desertification are found.

Building on early European knowledge of the benefits of windbreaks, the director of the experimental garden in Algiers proposed in 1847 planting a "belt" of at least four rows of trees along agricultural areas to protect agricultural fields from the drying desert winds and rehumidify the region (7). A quarter century later, in the 1870s, an influential colonist articulated the earliest notion of a "green dam" when he proposed planting lots of trees in southern Algeria to be "a dam of another sort" against the Sahara—one that would ameliorate the climate, temper droughts and also be "a source of revenue" from timber sold (8, p. 106).

European thinkers and politicians adopted these ideas widely by the last half of the nineteenth century, thanks to shared scientific networks, and they spread to most of Europe, including Russia, and to North America. The training of British, American, and European (including Russian) foresters at the world-famous French Forestry School in the last quarter of the nineteenth century, where such ideas were part of the curriculum, ensured their widespread adoption throughout most colonial territories and much of the rest of the world by the turn of the century (9).

By the early twentieth century, these arborocentric notions were informing many projects, including large-scale and state-directed reforestation and afforestation efforts in colonial dryland areas, often based on the rhetoric of the so-called encroaching desert (10). Fascination with reforestation was not limited to colonial territories, however, and massive reforestation projects were implemented in nineteenth century Europe and in the USSR, China, and the United States during the twentieth century. Often a favorite with authoritarian governments, tree planting was enthusiastically implemented in fascist Italy and in Nazi Germany (11). Many such projects have taken the form of shelterbelts, on which we focus here in dryland contexts.

Historical examples of state-led shelterbelt programs reveal the development of tree-planting as a form of environmentalism that suppresses certain cultures and ways of life through state-sponsored projects of territorial control (12). During the Dust Bowl period of the 1930s, the US Forest Service implemented the Prairie States Forestry Project (PSFP), for instance, to plant shelterbelts from Canada to Texas to mitigate soil erosion. Informed by desiccationist thinking popularized by Franklin Hough (Forest Service head) and Gifford Pinchot (trained in France), the PSFP was "a state-building project that marginalizes culture as it pacifies land," meaning that the government's use of an environmental solution to the industrially produced Dust Bowl conditions erased remnants of Native American land titles (12, pp. 107–9). Most authors agree that the program over-relied on fast-growing cottonwood seedlings to produce shelterbelts successful in the short term but less effective in the longer term when cottonwoods suffered from insufficient water (13).

Shortly thereafter, in the late 1940s, the Soviet Union implemented a shelterbelt program in the southern steppes as part of the Great Stalin Plan for the Transformation of Nature. Designed to halt the "desiccating Central Asian winds," ameliorate the climate, and temper droughts, the project planned eight large shelterbelts by planting approximately 5.7 million hectares of forest (11). Planting was chiefly carried out by employees of Stalin's government, with labor from collective farms (11). The Soviet plan built on much earlier ideas from 1890s Russia (14), including common European colonial notions of desiccation and overgrazing nomads, that fostered the influential narrative of "the struggle between the Russian forest and the Asiatic steppe" (11, p. 675). This all too common environmental and cultural trope used to justify tree planting is also found in many other parts of the world, including the United States, China, Russia, Africa, and the Middle East.

Stalin's plan is often criticized for its failure to consider soil composition or appropriate tree species (15). By 1954, internal reports indicated that more than half of the seedlings sown from 1949 to 1953 had died, and the climate of the steppe remained unchanged (11). Nevertheless, these Soviet efforts were influential in 1950s China. During 1950 to 1951, the government began to plant shelterbelts as Stalin's plan was being broadly publicized in China (16). Early Chinese plans resembled closely those of the Soviet Union.

Contemporary tree planting initiatives like green walls, therefore, are neither new nor innovative. They come with a long history that includes ecological misunderstandings of arid ecologies, of desertification, and of the benefits of trees. This has resulted in more failures than successes for afforestation projects. They also come with a significant history of top-down state implementation involving the political manipulation of local people that often further marginalizes already precarious populations (17). Despite this, the hype of green walls continues to be very influential in many parts of the world.

UNCOD: United Nations Conference on Desertification

3. GREEN WALL PROGRAMS

Two sets of programs figure prominently in contemporary green wall efforts: China's TNSP and two peri-Saharan programs, Algeria's Green Dam program in North Africa and the broader GGWI centered in sub-Saharan Africa. In all cases, green wall afforestation efforts overlap with social and political initiatives either formally within the same initiative or with other concurrent initiatives. For example, settling nomadic pastoralists in order to make them part of a network of socialist villages was one of the goals of Algeria's Green Dam program (18, p. 70). Likewise, the TNSP program shares with other Chinese ecological construction projects a geographic focus on the home territories of China's ethnic minorities, including Mongolians, Uyghurs, and Tibetans. Thus, these environmental improvement programs can provide the mechanism for internal territorialization by the state and in some cases the ecological resettlement of pastoralists and other groups (19). While understanding such political imperatives and contexts of green wall programs is important, the descriptions below focus on their afforestation efforts.

3.1. China's Three Norths Shelterbelt Program

China's TNSP has been called "the most extensive act of horticulture embossed on a terrestrial biome" (12, p. 171). It is focused on combating desertification, preventing the expansion of sandy areas, and mitigating erosion in China's North, Northeast, and Northwest, encompassing an area that includes 13 provincial-level units.[3] Sometimes referred to as China's Green Great Wall (or Great Green Wall), it has served as a reference point for subsequent projects around the globe.

The TNSP was launched in 1978, at the start of China's Reform and Opening Up. Shelterbelts were not new, however. From the 1950s to 1970s, other large-scale efforts had been implemented in the arid and semiarid North and Northwest (16, 20). Homelands of non-Han ethnic minorities, these lands were misunderstood through radically different Han Chinese landscape imaginaries as wastelands in need of improvement (21). During the Maoist period, desert areas were depicted as an "enemy of socialism" to be defeated by socialist struggle, including through the planting of shelterbelts, in projects that bore strong resemblance to Soviet plans (16). The TNSP emerged out of the intersection of this cultural and political history, together with growing domestic concerns about sand and windstorms, and the rise of global desertification discourses responding to drought in the Sahel region, including the 1977 United Nations Conference on Desertification (UNCOD) (12, 22).

Like its predecessors, the TNSP was often represented with images of an unbroken wall. Upon its launch, the *People's Daily* (23) heralded it as a "green, ten thousand-kilometer Great Wall" and imagined it as "a sand-fixing forest belt that will stretch unbroken." While grand in scale, this vision has from the beginning been implemented through a diverse system of agricultural shelterbelts, grassland shelterbelts, and erosion protection forests, rather than as a single, monolithic construction. In its first stage, the TNSP project area covered roughly 42% of PRC's territory, including 85% of its desert areas (24, 25). It was expanded to 45% of the country's area in 2011.

[3]These units include the Heilongjiang, Jilin, Liaoning, Hebei, Shanxi, Shaanxi, Gansu, and Qinghai provinces; Tianjin and Beijing municipalities; and Inner Mongolia, Ningxia, and Xinjiang autonomous regions. It is variously also translated as Three North Region Shelterbelt and the Three Norths Shelter System.

It is now envisioned as a 72-year project with a completion date of 2050, divided into three stages and eight phases, with a goal of increasing the project area's forest cover from approximately 5% to 15% (26). Recent government reports claim successful afforestation of more than 30 million hectares, or 13.57% forest cover in the project area (27).

SLCP: Sloping Land Conversion Program

Broad goals for the project are divided among its major regions: an agricultural shelterbelt system for the northeastern plains (often planting trees in a grid pattern around fields), windbreaks and sand stabilization in the northern arid areas, ecological and economic improvement via shelterbelts in the Loess Plateau, and a desert oasis shelterbelt system in the northwestern desert region. Afforestation is implemented through artificial afforestation (seedling plantations by human labor), land closure for natural regeneration, and aerial seeding (26).

Central government project documents for the more recent phases outline guidelines for where each method is appropriate, specifying rainfall, edaphic, and topographic criteria guiding which afforestation technique to pursue. For the project's fifth phase (2011–2020), the central government identified 15 focus areas and the counties they covered for project implementation, then offered funding for local governments to follow specific implementation models (26). A key problem of the TNSP has been inadequate central-level funding for the goals and implementation strategies pursued (28, 29).

An additional challenge has been the political economy of Chinese governance, which incentivizes the fulfillment of centrally set targets, the pursuit of funding opportunities by local officials, and projects that visually demonstrate achievements. As a result, the TNSP has notoriously pursued afforestation strategies that have favored fast-growing species such as *Populus* spp.[4] with a prioritization on the quantity of trees planted over diversity or survival rates. National Forestry and Grassland Administration documents show a growing recognition of problems of species selection, monocultures, and tree decline (27). A strategy of scientific greening is now emphasized, including a focus on shrubs rather than trees, multispecies plantations, attention to water conservation, matching species to local conditions, and natural regeneration (30).

Implementation of the TNSP has been a monumental effort. At the project's 40-year mark in 2018, the central government estimated total investments of 93.3 million renminbi (RMB) and the involvement of 313 million rural laborers (31). Labor is said to have contributed 53% of total investment, although notably it has included both uncompensated compulsory labor as well as wage labor. Although the TNSP is primarily a domestic program, the World Bank (32, p. 53) funded one TNSP project, the Ningxia Desertification Control and Ecological Protection Project.

While primarily defined as an antidesertification effort, the TNSP has also accumulated other rationales, including reducing soil erosion, driving economic development, and strengthening water security. Since 2000, when Beijing experienced intense spring dust storms, the TNSP has also been increasingly understood as a means of protecting downwind locations, shifting "from grand plans for conquering deserts into experiments in long-distance weather modification" (22, p. 21). Most recently, ameliorating global climate change through carbon sequestration has been added to the list of the TNSP's promises (27, 33).

Many difficulties plague an overall assessment of the TNSP over its more than 40-year history. These include changes in property rights, agricultural taxes, local government finance, and the organization of rural labor as well as a proliferation of other programs. It has substantial aerial overlap with several other large-scale ecological construction projects, particularly the Sloping Land Conversion Program [(SLCP) sometimes dubbed Grain for Green], which calls for afforestation on sloped arable lands and covers a broad area including the entire TNSP project area

[4]These are species of the genus *Populus*, including poplar, aspen, and cottonwood.

(34, 35). Multiple afforestation projects may be implemented in the same village (36) with studies most frequently evaluating all afforestation projects together, making it difficult to distinguish their effects (e.g., 34).

FMNR: farmer-managed natural regeneration

3.2. Sahara Initiatives

Since the colonial era, government forestry services have dominated environmental management and restoration visions in French West and North Africa (8). In 1972, Algeria announced its Barrage Vert (Green Dam) plan, which would combat desertification on the northern edge of the Sahara through the planting of a nearly continuous belt of Aleppo pines from Algeria's border with Morocco to that with Tunisia (37). The Algerian military led a planting effort of 6 billion trees over 3 million hectares during the first phase of the program (1972–1982), with the forestry department taking over subsequent phases due to poor tree establishment (37–40). Of all dryland afforestation programs in the world, the initial phase of the Green Dam project comes closest in practice to the green wall vision. As such, British forester Philip Stewart described it as an experience that is "one of the most bizarre in the history of world forestry" (38, p. 102).

While less ambitious than the Green Dam program, government ministries and international organizations have promoted afforestation programs in West African drylands since the 1970s. These include efforts to rehabilitate hardpan soils through earthworks to trap sufficient sediment and moisture to grow trees and other vegetation on the Mossi Plateau of central Burkina Faso (41, 42) and in the Keita Department of Niger (43), as well as efforts to reinvigorate agroforestry through improved management of tree coppicing, in the Maradi and Zinder regions of Niger, a management approach often referred to as farmer-managed natural regeneration (FMNR) (44–47). These programs, along with the ambitious vision of the Green Dam (48–50), inspired West African leaders to call for their own afforestation program across the region lying south of the Sahara Desert, the GGWI.

Heralded as an African-led movement,[5] the GGWI was approved by the African Union in 2007. Each signatory was expected to develop a national GGWI plan,[6] complemented by internationally led projects (52). While the attractiveness of the GGWI relied on the image of a literal green wall along the edge of the Sahara, on-the-ground realities of programs under the GGWI have deviated strongly in numerous ways. Actual afforestation efforts include FMNR activities within agricultural areas with a history of agroforestry, afforestation at earthwork-enabled rehabilitation sites on hardpan soils, shelterbelts (particularly in northern Nigeria), and discontinuous afforested lots in sandy areas with low population densities (often due to low water table) such as the Ferlo region of Senegal. As with later phases of Algeria's Green Dam program (50), afforestation constitutes a small fraction of GGWI expenditures. Now it is best understood as a rural development program seeking to improve climate resilience through not only afforestation but also soil and watershed management, local governance improvement, land tenure securitization, and expanding market access and investment opportunities (53, 54). Despite donors describing GGWI afforestation activities as more of a "mosaic" than a wall, references to the percentage of the wall that has been "built" (55) are evidence of the continued strength of the narrative.

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[5] Although the GGW is still described as an African-led movement, most of the funding and design comes from the international community. Major international institutions behind the GGWI include the European Union, the Global Environment Facility, the World Bank, and the United Nation's Food and Agriculture Organization. See Reference 51 for a full list.

[6] Original signatories included Senegal, Mauritania, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, Eritrea, Ethiopia, and Djibouti. While the GGWI includes countries in West, Central, and East Africa, the original green wall vision and early activity was centered in West Africa, the focus of this review.

Afforestation monitoring is generally centered on documenting activity completion (trees planted, farmers trained) rather than outcomes, such as tree survival rates and broader social and ecological impacts. As a result, claims of the GGWI's success are largely anecdotal, some of which illustrate afforestation efforts conducted prior to the GGWI (12). Progress has been hampered by a lack of donor follow-through and the deteriorating security situation in the region. Efforts to better coordinate activities and improve monitoring are ongoing. In advance of the 26th United Nations Framework Convention on Climate Change Conference of the Parties (COP26) in 2021, world leaders announced a new initiative, the GGW Accelerator, to jumpstart the program. The Accelerator's purpose is to both increase and leverage donor funding, as well as coordinate, monitor, and measure the impact of GGW projects with new emphases on green economic programs, carbon sequestration, and climate mitigation (56). A relaunching of the Green Dam was announced a few weeks after COP26 as part of the expansion of the GGWI, with the ambitious aim of extending afforested areas to 4.7 million hectares by 2035 (57, 58).

The TNSP and Saharan programs developed, evolved, and operate within very different contexts and with different socioecological goals and prerogatives. Still, they did not develop in isolation; experiences in one region influenced the programs elsewhere. As mentioned above, China's program was stimulated in part by the establishment of the UNCOD following the Sahelian drought. The GGWI was likewise stimulated by Algeria's Green Dam program, which in turn was relaunched in the context of the expansion of the GGWI (GGW Accelerator). The GGWI has in turn been supported by Chinese technical assistance based on China's dryland afforestation experience in its shelterbelt programs (59).

Compared to the other two programs, the GGWI has a shorter record of ecological and social impacts. In all cases, these programs follow previous initiatives and overlap with others, complicating any assessment of their impacts. This problem is exacerbated by the limited monitoring conducted by these programs with most attention directed at tree planting data and limited attention given to the ecological and social impacts of afforestation.

4. ECOLOGICAL IMPACTS

Green walls are efforts of large-scale afforestation in arid zones to combat desertification and, increasingly, over the past ten years, to increase carbon sequestration (60, 61). A review of their mixed ecological effects is complicated by not only the wide variability of the types of afforestation efforts falling under the term green wall but also their implementation in diverse environments. The Mediterranean semiarid and arid climate of the Green Dam in Algeria and the temperate continental monsoon climate of the TNSP area in northern China are characterized by quite different temperatures, wind patterns, rainfall seasonality, and soils from those found in the semiarid tropics of the West African GGWI region, which is dominated by a monsoonal climate with a distinct monomodal rainy season of two to four months a year.

The regional ambitions of these programs belie their large ecoclimatic diversity. The Green Dam program is geographically more restricted in area (a 20-km by 1,500-km strip), with afforestation efforts concentrated on an elevated plateau with soils of low nutrient content and basic pH with calcareous crusts common (37). Long-term average rainfall varies between 200 and 300 mm/year with the dominant vegetation composed of perennial grasses, seasonal annuals, and sagebrush with patches of oaks, junipers, and pines in moister areas (37, 40). GGWI afforestation programs exist across a much broader bioclimatic gradient consisting of the entire Sudano-Sahelian zone with annual rainfall varying from 200 to 1,200 mm/year. Soils vary from coarse sands of variable depths, silty-clay depression/floodplain areas, and surface or near surface crusted soils including ferricrete and hardpan areas. In the north, rainfall varies from 200 to

800 mm/year; vegetation is dominated by annual grasses. Further south, perennial grass and tree/shrub cover increase to open savanna. Approximately two-thirds of the TNSP area is arid and semiarid with a mean annual precipitation of less than 400 mm (62, 63). The area is dominated by aeolian sandy soil with rainfall, vegetative cover, and soil organic carbon declining from east to west. At all three program areas, ecoclimatic variability significantly affects the prospects and broader impacts of afforestation efforts.

Despite this variability, all three regions are relatively arid with poorly developed surface soils of low organic matter content. Thus, vegetative growth is often multiply constrained with the planting of trees necessarily having trade-offs with respect to access to water and the growth of surrounding herbaceous vegetation. Recognizing the multiple constraints to plant growth within green wall project zones, the planting of trees in arid and semiarid areas will have complex ecological effects beyond simply an increase in trees (64, 65). Proponents of dryland afforestation point to the possibilities of reduced surface wind speeds, reduced evaporation, stabilization of mobile dunes, cooling and humidification, and a net increase in surface soil deposition, which may increase soil fertility (45, 66, 67). At the same time, higher tree densities may increase transpiration, lower groundwater table levels (35, 61, 68–71), reduce stream flow (65), and reduce the cover of shrubs and grasses (37, 68), which may in turn increase water and wind erosion (37, 72, 73). In short, despite visionary statements in support of the ecological benefits of trees, the broader ecological effects of tree planting in multiply constrained arid environments are not clear (4). Thus, monitoring of these ecological effects is most important.

Green wall projects require large-scale mobilizations of capital and human labor by governments, NGOs, and international agencies that often necessarily disrupt rural peoples' access to resources. Monitoring of their technical success as well as of their broader ecological and social impacts reflects the capabilities of local units (NGOs, local governments, villages), positioned within hierarchical structures, to manage and mobilize rural people to enact greening visions. Unless prescribed and strongly enforced by higher authorities within governance structures, monitoring is not likely to be rigorously practiced. At most sites, any monitoring and assessment is performed by the agencies or organizations in charge of tree planting.[7] For the GGWI, impact measures tend to be short term, focused on the planting process (trees planted, farmers trained, laborers hired), with little effort to measure technical success, let alone broader impacts over time (53). As government-organized programs, both Algeria's Green Dam and China's TNSP programs have greater potential for more coordinated monitoring programs. Unfortunately, monitoring efforts are sparse, with similar preoccupations with tree planting and short-term survival and limited attention to broader ecological (or social) impacts. Given their politically sensitive nature, these data are often treated as proprietary with local governments reporting aggregate values of afforested areas for their jurisdictions that are often not supported by independent assessments (74).

As a result of the combination of a lack of monitoring effort and the treatment of monitoring data as proprietary, there is very little publicly available data to independently assess green wall outcomes. Institutional proponents of these programs cite aggregate measures of success (hectares forested or number of trees planted) but very rarely make available the locations of planted areas. Many of these promotional statements raise concerns that green wall programs may be inaccurately claiming credit for increases in vegetative cover through natural process or through (prior or concurrent) efforts outside of these programs. As a result, independent assessments of the planting success and broader ecological impacts of these programs cluster around two types: (*a*) regional assessments of changes in vegetative cover relying on remote

[7] Short-term monitoring by a third party is now required in China's TNSP.

sensing and (*b*) spatially and temporally circumscribed field observations on planting success and ecological impacts. Both types of assessments have their strengths and weaknesses and very rarely are they combined in multiscalar assessments. Therefore, we discuss each separately.

4.1. Remotely Sensed Ecological Assessments

Given the huge investments into these green wall programs, there is considerable interest in analyzing their success within policy and scientific circles. Without information about the location of afforestation sites, external assessments rely heavily on remote sensing. Work is dominated by studies that seek to document changes in vegetative cover (with or without distinguishing cover types) within districts where afforestation programs operate. In arid areas where these projects are implemented, vegetative cover (including tree cover) varies significantly as a result of interannual variation in rainfall (75).[8] To assess the ecological effects of afforestation, it is important to (attempt to) distinguish rainfall effects from the presumed positive effect of green wall programs that purportedly lead to greater success of tree establishment than from natural afforestation.

In general, remote sensing work cannot assess the range of secondary ecological effects that planted trees have and are plagued by interpretation problems if variation in rainfall is not controlled for. Average rainfall for significant areas of both China's TNSP region (62, 74, 77, 78) and the Sahelian GGWI region (79, 80) is higher over the past 25 years compared to the previous 25 years.[9] These rainfall trends raise concerns about evaluations of Chinese programs that point to environmental rehabilitation success through regional changes in vegetative indexes like the Normalized Difference Vegetation Index (84–86) or decreasing dust storms (24, 87) without considering climate trends. In West Africa, such claims are not generally made, but there is broad recognition of widespread greening of the region since the severe dry period of the 1970s and 1980s (42, 88–91).[10] When efforts have been made to control for the effects of rainfall variation on vegetative cover indexes, some studies point to the dominance of rainfall variation with very little evidence for a measurable effect of green wall programs on vegetative productivity at broad scales (74, 88, 89, 91, 93) while other studies have pointed to green wall intervention zones showing greater vegetative cover gains than would be expected from rainfall alone (76, 90, 94–96). Often these areas are affected by afforestation efforts that preceded or now run concurrently with green wall programs.[11]

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[8]A persistent monitoring challenge in the world's drylands is to disentangle the effects of human management and rainfall variation on vegetative cover (76). The history of the desertification is a history of the conflation of the effects of climatic variability and human management on vegetative cover (6).

[9]These regional trends hide intraregional differences in rainfall history (62). Moreover, rainfall has become poorly distributed in the Sahel, with more rain falling in large events (81, 82). In Algeria, the rainfall trends have been in the opposite direction, with a general drying trend in the country since the early twentieth century, with the largest rainfall declines seen in the southwest and the smallest in the northeast (75, 83).

[10]The extent of vegetative recovery has been found to vary by edaphic type, with most recovery occurring in sandy slopes/plains and depression areas while shallow soils on laterite or rock outcrops show little greening (88). Moreover, some have found evidence that changing magnitudes and distributions of rainfall have very much led to natural regeneration of tree and shrub cover (92).

[11]In West Africa, two anomalous areas with higher than expected productivity are the Mossi Plateau in Burkina Faso and the Maradi/Zinder area of Niger. The former is an area where significant investments were made by NGO-supported farmers to rehabilitate upland hardpan areas through various earthworks and to revegetate dune areas (41, 42, 97–99). The latter is an area where FMNR of trees in farmer fields was "discovered" and promoted (44). Both these areas involved farmer actions and development activities that preceded the GGWI, but their success is a major motivation for the potential of future GGWI impact. Local studies provide a more complex story of overlapping priorities and mixed results of these development initiatives (53).

While remote sensing analyses are widely used to support positive effects of green walls, a serious review of these studies shows limited and mixed effects of these investments at the regional scale once rainfall is controlled for. Still, remote sensing studies that seek to control for rainfall variability have distinct limitations, which may hide positive effects on vegetative cover. Rainfall, vegetative index, and project intervention data are spatially coarse with estimates of productivity highly sensitive to aggregation methods (89). Data coarseness may hide more localized effects of tree planting initiatives, but such effects will only be observed if the locations of these interventions are recorded followed by controlled tracking of these sites over time (100).

4.2. Field Studies of Ecological Impact

Afforestation has long been globally promoted by forestry interests with a bias toward monocultures of fast-growing timber species. These efforts have reduced biodiversity in favor of exotic monocultures protected as forest reserves for timber, thus reducing the usefulness and availability of afforested areas to local communities. Green wall projects have been influenced by this forestry tradition (101), which raises numerous concerns. First, as noted above, the dryland areas targeted for green walls may be more suited for grasslands and steppe than woodlands, let alone forests (9, 65, 102–104). Second, tree species choice may not be ideal. There is a long history in the Sahel region of introducing exotic tree species with mixed results (105). *Populus* spp. were very much favored by the Chinese government during the first two decades of the TNSP, as were Aleppo pines during the first phase (1972–1982) of Algeria's Green Dam program (37–39). The high water demands of these trees (37, 68), their vulnerability to disease (37, 106), and their limited uses for local communities contributed to their poor establishment. At all sites, new approaches have sought to expand the range of tree species planted as well as grasses and shrubs (65, 107). For example, subsequent planting of fruit trees in areas of the TNSP with sufficient rainfall have shown greater success and support by local communities (108).[12] Likewise, the Algerian Dam (37, 109) and GGWI programs have expanded their species planting portfolios (110, 111). Still, there remains an ongoing tension between interests in the rapid establishment of tree cover and in sustaining native biodiversity.

Survival rates of planted trees are rarely reported, reflecting not only the political importance of programmatic success but also the incoherence of these programs. Outside of Senegal, GGWI programs are not strongly organized by state ministries but instead by a mix of local governments and NGOs who often communicate directly with international funders. Under these conditions, tree planting effort (number of trees or area afforested) is recorded, but there is no systematic monitoring of tree survival.[13] Given higher levels of involvement by the state and their longer histories, there are survival rate numbers available for the Green Dam, TNSP, and Senegalese GGWI programs. Still, these estimates vary widely due in part to differences in the temporal evaluation window and variable biophysical and management conditions. Published survival rate estimates range from 40 to 60% for the TNSP (64, 78, 107)[14] and from 30 to 40% for the early phases of Algeria's Green Dam program (37, 39, 40) and for the Senegalese GGWI project (114). Rates have been found to be lower in drier areas (62, 78, 115), during drier periods (116–118), and with closer spacing of planted trees (119).

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[12] During the third phase of the Green Dam program, higher survival rates of fruit trees were reported (39).
[13] Such planting statistics often overestimate actual live trees in the ground since trees planted to replace dead trees are included in these statistics (53).
[14] Cao (112), however, provides a 15% survival rate estimate for all tree planting programs in arid and semiarid regions of China (since 1949), although this estimate has been strongly questioned by Yang & Ci (113).

Despite the dearth of rigorous field studies, several observations of tree management are illustrative. First, it is clear that planted trees are often not sufficiently adapted to the dryland conditions where they are planted. Not only are survival rates low but also irrigation has been found to be necessary in drier areas within the TNSP (69, 120), the Green Dam (37, 39), and the Senegalese GGWI project (121, 122) areas, at the sapling stage and beyond. Such management undoubtedly lowers water availability for natural vegetation and for animals (humans and wildlife), not only at the site but also potentially more broadly through effects on run-off/run-on and water table depth. Consistent with this is work that has measured reduced soil moisture regimes when a range of vegetative cover types have been afforested (123) and some evidence for soil desiccation, tree stunting, and limited regeneration (68, 124, 125). In short, afforestation in dryland areas has often led to a combination of poor tree survival, tree stunting, and reduced water availability, with implications for water erosion and the viability of life forms other than trees.

A potential ecological benefit of green wall projects is that the trees serve as a barrier to wind, thus reducing wind erosion and increasing deposition of wind-borne dust, which may, in turn, increase the fertility of local soils. This is an emphasis of the TNSP program where wind-borne dust from northern China has had a significant effect regionally, including in Beijing, the country's capital (87). In contrast, coarser soil textures and the relatively higher rates of water erosion tied to a monsoonal climate have led to a smaller benefit for GGWI locations. Planting shelterbelts around fields is a well-established and recognized practice around the world to reduce net wind erosion. Still, studies have also pointed to the effectiveness of the spontaneous growth of herbaceous cover in reducing wind erosion (126). Empirical field-based studies on net erosion rates are difficult to conduct and assess, not only with respect to measurements of soil loss but also with respect to the net effect of planted trees on herbaceous vegetation cover that may protect soil without human intervention. Work in the TNSP study area has shown a reduction of net erosion in fields protected by shelterbelts (67, 127) with some benefits to crop productivity (128). Still, there are limits to trees serving as physical barriers to sand movement, with observations of Green Dam trees in Algeria being essentially smothered by moving sands (129).

The effects of the shelterbelts on water erosion are less clear, with some empirical work finding little difference between planted grasses, shrubland or forest in water erosion rates (130), and other more anecdotal observations pointing to increased water erosion in tree plantations due to reduced vegetation cover near the soil surface (37, 73, 112). Studies on soil fertility in TNSP afforested areas show mixed effects. For example, soil fertility parameters (N, P, K, organic matter) differ very little in shelterbelts compared to nearby fields, except for reductions in bulk density and higher potassium levels in shelterbelt soils (131) consistent with greater dust accumulation in shelterbelts. One meta-analysis found an increase in soil fertility (organic matter, N, P, K) in afforested areas older than 30 years compared to "abandoned land" and "cropland" (132). Interpretation of these findings is difficult since the study was not controlled and provided little reference to the mechanisms behind improved chemical fertility.

5. SOCIAL IMPACTS

The stated goals of green walls are primarily ecological—reclamation, antidesertification, and carbon sequestration—with social benefits to inhabitants seen as either inherent or secondary to the improved ecological productivity and resilience that may stem from afforestation. The ecological effects of these programs, as presented above, call into question the social benefits that are purported to accrue. Across cases, donors and program implementers largely assume general social benefits to local residents living in degraded landscapes through increases in ecological productivity (28, 45, 133, 134). These assumptions persist even though increased arborescent cover “does not necessarily translate into improved livelihood conditions” (52, p. 1420; 53). Program documents point to several direct mechanisms behind presumed social benefits: increased food production; increased income through direct job creation (labor for planting, earthworks, guarding) or through the production of timber and nontimber products such as fruit, gum arabic, and medicinals. A commonality of all references to social benefits of these programs is that they not only lack empirical evidence but also ignore social costs tied to these programs, such as enclosing areas for afforestation that local communities rely on.

The actual social impacts of green walls and shelterbelts are remarkably understudied. The consensus in the literature is that there has been little to no such monitoring of Algeria’s Green Dam activities. In China, official assessments have focused primarily on monitoring ecological benefits (135), and while government documents specify that certain aspects of social impacts are included in project assessments (136), the results of these official assessments are not publicly available. Such assessments are lacking in the GGWI case as well, where project documents purporting to discuss social impacts only list activity metrics such as the number of people (or sub demographics) in the intervention zone, the number of people trained, or the number of people paid as laborers. GGWI success stories, particularly those conveyed in the press, tend to be both anecdotal and repetitive (12). The few social impact studies that do exist focus almost exclusively on increased household income or overall economic benefit, whether through sales of cash crops associated with trees or income from labor payments for tree planting (32, 137, 138). In such assessments, little to no attention has been paid to the distribution of benefits; potential negative effects of planting trees, including increased water demand; or changes to property rights, enclosure, and attendant loss of access to livelihood resources.

While successful afforestation efforts hold promise of long-term public benefits through environmental improvements, direct costs and benefits are often unequally distributed with benefits enjoyed by the powerful and the costs borne by the most vulnerable. At a fundamental level, the increased carbon sequestration through afforestation of dryland areas will provide global benefits but may harm the most vulnerable residents in some of the world’s poorest areas. In the short term, there is evidence for local elites using GGWI projects to claim more resources (53, 114, 122), whereas in China, local village leaders may benefit by owning and renting out the necessary equipment for tree-planting projects (e.g., 36). In the longer term, the focus on restoring land in ways to make it more attractive to private (including foreign) investment (54, 139) may lead to further expropriating lands from the rural poor.

The most cited direct social benefit to local communities in GGWI project documents and the testimony of local informants (53) is the creation of manual labor jobs to prepare the surface for tree establishment, to plant trees, water trees, and guard enclosures. Despite the rhetoric of program promotion,[15] many of the jobs created by these programs are short term and unreliable. In West Africa, most of these jobs have been paid through food- or cash-for-work programs with evidence of access to these jobs in Niger being biased against the truly vulnerable. Access was through male heads of household, and therefore women with husbands on labor emigration had a more difficult time obtaining work (53). Longer-term work opportunities created by the GGWI are few (primarily guards for afforested areas). In Senegal, it is reported that such opportunities have been given to people from outside of project communities with ties to the project leaders (121).

[15]The Great Green Wall Accelerator, for example, has a goal of creating 10 million green jobs in rural areas (**https://www.unccd.int/our-work/ggwi/great-green-wall-accelerator**), a much higher figure than the reported 350,000 jobs created between 2007 and 2018 by GGWI activities (140). While such job estimates are generally not explained, afforestation activities themselves provide only a limited number of short-term manual labor jobs.

Labor mobilization for China's TNSP programs has varied over time and region and is also influenced by concurrent implementation of other ecological programs. Reports of total investments into the TNSP often include discussions of the so-called labor of the masses. Zhao (28) claims that between 1977 and 2007, the converted value of labor accounted for 78% of total investment, and Zhi et al. (29) calculate 3.98 million peasant-days of labor between 1978 and 2000 in Ningxia. Compulsory labor has become less common over the decades of the TNSP but is still required by village leadership in some areas. In areas where the TNSP takes the form of windbreaks, planted around the sides of roads, ditches, and canals, farmers may plant on their own farmland or on village collective land, through village compacts on compulsory collective labor. Currently, however, it is much more common for tree planting operations to be contracted by private companies, individuals, or cooperatives, which then hire either resident farmers or nonlocal workers for daily labor (100 RMB/day in villages in Qinghai in 2022).

The ecological effects of the green wall programs can have positive social effects through increases in productivity and resilience of vegetative growth. Most of these effects are seen as beneficially affecting soils through reduced erosion, improved soil fertility, and increases in soil moisture due to reduced evaporation from soil surfaces. However, these positive effects on vegetative productivity will, if they occur at all, only develop over decades (where planted vegetation survives), and current ecological monitoring programs are insufficient to demonstrate these benefits. The ecological effect with the most immediate social effect has been the greater water demands of trees both during and after their establishment (irrigation requirements and lowered water tables). While not well-documented, these demands undoubtedly negatively affect local communities by making water access more labor intensive and economically costly (141). In China, studies that attempt to account for indirect costs of implementation, including water opportunity costs, find that afforestation results in a net loss of economic benefit (108, 142, 143). Even for trees that are more suitable for arid conditions, establishment often requires regular irrigation that may compete with the other water needs of local communities. In places with deep water tables and year-round settlement, such as the Ferlo region of northern-central Senegal, the increased water demand for GGW nurseries has created significant hardships for residents (121, 122). Local pumps cannot keep pace with the demand generated by tree nurseries, forcing families to wait up to three days to refill their cisterns and obtain water for their animals; families report reducing water use for hygiene, providing smaller amounts of water to their animals and losing time spent in school or on other income-generating activities (121, 144).

The tree species planted have a strong effect on residents' acceptance of afforestation efforts, with measurable effects on tree survival rates. After decades of promoting species of less value to local people (Aleppo pines and poplars), both the Green Dam and TNSP programs have shifted their emphases toward fruit trees and other commercially attractive tree species (138). Responding to these experiences, many afforestation efforts of the GGWI rely on *Acacia senegal*, a native tree to the region that produces gum arabic. In sum, there has been a significant trend away from exotics and trees having few economic benefits to native tree species and those with economic benefits.

Afforestation on land held by individuals has different social effects than on land held in common. Afforestation initiatives are most often directed at common lands in both the Green Dam and GGWI program areas. In China, the TNSP targets both land whose use rights have been allocated to individual households (whether cropland, forestland, or rangeland) as well as village common land including that designated as wasteland. For individuals, the incorporation of trees into croplands as either agroforestry or shelterbelts has mixed short-term and longer-term effects on crops. Farmers may resist such planting due to concerns about heightened competition for moisture, light, and nutrients. Where TNSP and SLCP implementation have overlapped in

China, the emphasis is on replacing cropland with forests, with increased off-farm income touted as a benefit of the program (35, 145).

On common lands, afforestation programs produce patterns of exclusion. In the short term, people and livestock are excluded from afforested areas to allow for tree establishment. Once and if established, the usefulness of afforested areas, through their transformation of vegetative cover, is changed for different members of local communities. Conversion of pastures to tree-covered areas may lead to a net negative impact through a loss of forage with differential damage to those dependent on common areas for livestock grazing and gathering. In the world's drylands, mobile livestock rearing is a major livelihood strategy in response to climatic change and variability. This is true for all rural residents, not just those who are nomadic. These benefits of livestock rearing depend on access to common pastures.

Thus, a major negative social effect of green wall enclosures is their impact on the livestock sector, with these negative effects sometimes explicitly acknowledged but unaddressed by program promoters (137). Expansion plans for the GGWI stipulate that up to 3 million hectares will be off-limits to any grazing for an unspecified period (146). Tree lots in the Ferlo region of northern-central Senegal, and Niger, for example, consume pasture and block livestock corridors and access to water points, creating significant hardship for residents (53, 121, 122). Algeria's Green Dam was implemented predominately on prime pasture lands, and it is widely acknowledged that the native vegetation was severely damaged and pastoral livelihoods disrupted in the project's early decades (37, 39, 40). Pastoralists were banned from most afforested areas with migration pathways disrupted and rangeland vegetation plowed under to make way for pine plantations. In short, "all the people living in the path of the belt were evicted" and their lands expropriated (147, p. 19). Other authors have noted local populations' often-serious resistance to tree plantations usually targeted for communally held lands used for pasturing livestock (37). However, these exclusions typically occur with little acknowledgment or thought on the part of different programs.

In China's TNSP, processes of enclosure have been linked to the overlapping "retire livestock, restore grassland and forest" (*tuimu huanlin huancao*) project, which targets purportedly overgrazed pastures for enclosure and removal of livestock grazing seasonally, for three, five, or ten years, or permanently, sometimes in conjunction with aerial seeding of grass and also planting of shrubs.[16] This is often accompanied by ecological resettlement. In one case study in Alxa, Inner Mongolia, displaced former herders have been provided subsidies that are inadequate to cover living expenses. With neither employment nor enough to live on, they were seen by local governments as both a potential threat to social stability as well as a potential labor force for planting trees. Thus, precarious former herders have been enrolled as a flexible labor force for TNSP activities including planting shrubs and saplings and collecting, sorting, and selling seeds (22, pp. 63–68).

Another case is a Ningxia TNSP project partially supported by the World Bank (32), which noted significant livelihood displacement due to enclosure of grazing lands in Yanchi, Ningxia. Mitigation of these impacts consisted of alternative livelihoods provided by the establishment of 2,134 hectares of *Cerasus huimilus* (Chinese dwarf cherry) and *Lycium barbarum* (Chinese wolfberry) crops for commercial sale, although these would not have been available for sale right away due to growing time.

The negative effects of enclosure on livestock rearing are troubling and show international agencies' and state governments' disregard of mobile livestock husbandry's relationship with

[16]Although compensation was provided, at least in the case of the "retire livestock, restore grassland and forest" project, it was often reported to be inadequate, creating lower standards of living after enclosure, although in some cases this negative effect was diminished due to a lack of actual implementation (36).

dryland climate resilience. Instead, these actors use ecological rehabilitation as a pretext to settle nomads and transition livestock rearing to more "modern pursuits." This deviates from current understandings of the important role of mobile forms of animal husbandry in dryland climate resiliency (148). While difficult to quantify, the reduction of pasture and sedentarization of livestock husbandry in these regions may outweigh any benefits of tree planting on socioeconomic resilience to climate variability.

6. CONCLUSIONS

The green wall, as an environmental and social rehabilitation structure, has long been an influential myth. False starts and failures of green walls since the nineteenth century result from three misguided notions: desertification as marching deserts, dryland homogeneity, and arborocentrism. The view of deserts as continuously expanding, fueled by human mismanagement, and degrading productive land along a broad front is an old and discredited notion. Oscillations of desert "edges" bordering semiarid zones are driven more by variations in climate than by human mismanagement. In short, the science strongly suggests that widespread devegetation is primarily caused by climate. Planting trees in these areas is rarely successful without irrigation. Outside observers have long viewed drylands as homogeneously barren, and thus the seductive idea of regional transformation by planting a swath of trees across a large area appears simple. In fact, these landscapes are biogeographically and socially complex. As a result, target regions are interrupted by complicated edaphic and topographic factors and the residents of affected areas may rightfully see green walls as a threat to their livelihoods. Arborocentrism, which promotes trees as the best vegetative form, signifying environmental health, has contributed to an emphasis on dryland afforestation rather than other forms of vegetation such as grasses and shrubs that are often more suitable for dryland ecosystems.

Dryland green walls have mostly failed to achieve their objectives, as demonstrated in our review. The early phases of Algeria's Green Dam program came closest as an attempt—but one that ended in failure for much of its 1,500-km length. Early visions of the TNSP and the GGWI were consistent with green wall single-species afforestation, but when confronted by dryland realities, program plans moved away from this type of afforestation. Instead, they, like Algeria's Green Dam, have adopted mosaics of different types of multispecies dryland afforestation (e.g., shelterbelts, afforestation blocks, agroforestry). Still, governments and international institutions continue to promote green wall programs (especially the GGWI). The green wall narrative sustains interest and generous funding. It also maintains the idea of a coherent regional environmental rehabilitation program that supports top-down territorialization interests of national governments and international institutions concerned with economic development, political stability, migration, and security. The environmental rehabilitation aims of these programs cannot be divorced from the political goals of powerful institutional actors. Although significant financial investment and human effort goes into such tree planting projects, there is remarkably little publicly available information about their technical success or their broader and social effects, a key area for future research.

Synthesizing the available evidence collected from sources that are temporally and geographically circumscribed, we draw numerous conclusions. These programs have a mixed record in terms of technical success, usually simply measured by the survival rate of planted trees. Losses are most often associated with lack of sufficient moisture (higher losses in more arid areas), inattentive tree care (useful trees have higher survival rates), and disease (prevalent with monocultures). While difficult to assess, there is some evidence that tree cover, as with other forms of vegetative cover, can reduce net wind erosion rates and thus theoretically could, over many decades, help improve soil structure and fertility. Increasingly, dryland afforestation advocates also point to its carbon sequestration benefits and label it a nature-based solution to climate change.

These potential longer-term benefits, however, are countered by the more rapidly and frequently observed damage to native vegetation and increased demand for water that come with afforestation. Reduced soil moisture and water table depression have been observed in several localities that likely have negative effects on surrounding vegetation and human livelihoods. In dryland areas, afforestation may also lead to conversion of grassland and steppe to forest, making landscapes often less biodiverse and less useful to local people, particularly those relying on livestock. In sum, expecting some of the poorest people in the world to bear the costs of afforestation in the short term (water scarcity and exclusion from land) for potential, but not guaranteed, longer-term (soil improvements) or global benefits (carbon sequestration) is problematic and unjust.

The dryland afforestation programs reviewed here vary significantly in their institutional configuration from nationally mandated and implemented efforts (Algeria) to nationally mandated and locally implemented designs (later phases of the TNSP), to mandates and implementation developed with significant but uncoordinated international involvement (GGWI). Such programs, in different ways, provide opportunities for resource capture by local elites, at the cost of vulnerable social groups, particularly pastoralists, being excluded from their resources. By creating barriers to livestock mobility, afforestation erodes the climate resilience of dryland economies (148).

Efforts to rehabilitate degraded dryland areas by increasing vegetative productivity should focus not solely on trees but rather on types of more locally useful vegetation. Such initiatives should be informed by detailed understandings of local resource tenure and seasonal use patterns. There is a significant need for in-depth case studies on the sociocultural and political economic dimensions of shelterbelt afforestation projects, with a focus on how such programs may change property rights, access to resources, income, and employment as well as alter the distribution of wealth and power. Furthermore, monitoring systems should be established to better track the long-term effects of revegetation on vulnerable local people. It is only through transparent and community-engaged work that such programs can lead to ecological and social benefits for residents of dryland areas who are arguably some of the most exposed and vulnerable to climate change in the world.

SUMMARY POINTS

1. The top-down environmental rehabilitation strategy of green walls is derived from problematic ideas of the marching desert and arborocentrism and has experienced a long history of failures.
2. Current programs of dryland afforestation depend heavily on the green wall vision to garner popular and financial support but then deviate strongly from it in practice.
3. Understanding social and ecological impacts of dryland afforestation is hampered by inadequate monitoring with data collection focused on tree-planting statistics. This reflects programs' presumptions of socioecological benefits while ignoring potential costs/harms.
4. Empirical support for widespread ecological benefits of dryland afforestation is limited and inconclusive. The primary benefit appears to be reduced wind erosion in some locations. This is balanced by many costs, however, including soil desiccation and decreased biodiversity in many others.
5. The social benefits of dryland afforestation are limited, especially in the short to medium term, while costs are high, particularly for herders dependent on commonly held rangelands.

6. While promoted as a means of increasing dryland resilience to climate change, empirical evidence suggests that green walls do little in aggregate and may exacerbate the vulnerability of the most precarious populations.

FUTURE ISSUES

1. Ecological trade-offs in dryland afforestation are an issue that provides a more in-depth review of existing empirical literature on the ecological costs and benefits of dryland afforestation (carbon sequestration, erosion, water availability, biodiversity, etc.).
2. Improved monitoring of dryland afforestation initiatives is an issue that reviews best practices in social and ecological impact monitoring of afforestation projects to address current lack of monitoring.
3. Building social and ecological resilience in the world's drylands with nature-based climate solutions is an issue that would review the existing literature on climate vulnerability and resilience of dryland livelihoods and how these are impacted by major climate mitigation and adaptation interventions.

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