diversity

MDPI

Review

Management Strategies of *Prosopis juliflora* in Eastern Africa: *What Works Where?*

Hellen Wangechi Kamiri [1,2,*], Simon K. Choge [3] and Mathias Becker [2]

[1] Department of Agricultural Sciences, School of Agriculture and Biotechnology, Karatina University, Karatina P.O. Box 1957-10101, Kenya
[2] Department of Plant Nutrition, Institute of Crop Science and Resource Conservation (INRES), Karlrobert-Kreiten-Str. 13, 53115 Bonn, Germany; mathias.becker@uni-bonn.de
[3] Kenya Forestry Research Institute (KEFRI), Baringo Regional Forestry Research Centre, Marigat P.O. Box 57-30400, Kenya; s.choge@kefri.org
* Correspondence: hwangech@uni-bonn.de or hkamiri@karu.ac.ke

Abstract: *Prosopis juliflora* is a shrub/tree originating from the Americas. Since its introduction for fuel wood afforestation into eastern Africa, it has been invading crop- and rangelands with negative effects on the environment and on livelihoods. Understanding the management strategies for *Prosopis* and matching them with ecological, social-cultural, and economic needs of the eastern African region is a pressing scientific issue. We analyzed management strategies of *Prosopis*, focusing on determinants and drivers of their choice of applied management strategies as well as their effectiveness. We identified 1917 scientific contributions published between 1970 and 2022. Following a multi-step screening, we reduced the references to 53 relevant (internationally) published papers with a focus on the management of *Prosopis* in the east African region. Analysis of the literature shows that factors driving invasion dynamics but also land users' social-economic as well as cultural attributes determine the type of management strategy and shape local control actions. Main strategies comprise (1) physical containment of invasive spread, (2) chemical, mechanical and biological approaches to reduce stand densities, (3) complete eradication, (4) restoration of invaded land, and (5) economic use of *Prosopis* products. Adopted strategies are based on actual and perceived impacts of invasion, and the adoption and success of individual strategies is highly location specific.

Keywords: eastern Africa; invasive species; *Prosopis juliflora*; management; niche-specificity

check for updates

Citation: Kamiri, H.W.; Choge, S.K.; Becker, M. Management Strategies of *Prosopis juliflora* in Eastern Africa: *What Works Where? Diversity* **2024**, *16*, 251. https://doi.org/10.3390/d16040251

Academic Editors: Zigmantas Gudžinskas and Kevin Cianfaglione

Received: 19 February 2024
Revised: 3 April 2024
Accepted: 3 April 2024
Published: 22 April 2024

1. Introduction

Biological invasions have steadily increased over recent centuries [1], with vascular plants comprising the largest group of potentially invasive organisms in African rangelands [2]. The spread of invasive alien plant species is recognized as a global problem with severe impacts on livelihoods [3], on biodiversity [4], and on the wider environment [5]. Globally, invasive species pose significant threats to agricultural land, leading to reduced productivity, crop loss, and consequently, to poverty and food insecurity. In addition, considerable soil quality deterioration due to alien plant invasions and loss of critical habitats have resulted in reduced capacity of rangelands to support livestock, and to meet the needs of pastoral communities, thus leading to conflicts [6] and indirect effects on human health [7,8].

In eastern Africa, 210 alien plant species were identified in the Global Invasive Species Database [9], with largest shares (number of alien invaders) occurring in Kenya (49) and Tanzania (48), followed by Uganda (33) and Tanzania (11), while the rest are spread in other eastern African countries [10,11]. Among the most common alien invasive plant species in the region is *Prosopis juliflora* (Swartz) DC, hereafter referred to as *Prosopis.* The World Conservation Unions lists *Prosopis* among the 100 of the "world's worst invasive alien species" [9,12,13] due to its rapid invasive spread, its massive effects on agricultural and grazing lands, and thus on the livelihood of communities in the drylands of eastern Africa. Today, *Prosopis* reportedly poses a threat to human and animal life in Ethiopia, Kenya, Somalia, Rwanda, Sudan, Djibouti, Eritrea and Tanzania [14].

Prosopis is a thorny evergreen perennial shrub/tree native to dryland areas of Mexico, South America and the Caribbean. It belongs to the Fabaceae (sub-family of the Mimosoideae) and can fix atmospheric nitrogen with rhizobia from the cowpea group [15]. As a phreatophyte (plant requiring access for its roots to shallow groundwater tables of <3–5 m), it populates mainly littoral zones of lakes, floodplains and inland valley wetlands, and areas around boreholes, canals and other irrigation infrastructure [16]. *Prosopis* is easily naturalized in tropical regions, and this is explained by its allelopathic nature, repeated flowering, and coppicing ability [17,18]. It also produces a huge seedbank of viable seeds which are easily dispersed through livestock movement and through irrigation canals [19].

The earliest *Prosopis* introductions into Africa were in Senegal in 1822, in Sudan in 1917 [20], in Kenya in 1948, and later in Ethiopia and South Africa in the 1970s and 1980s [16–18,21]. In all cases, introductions aimed at addressing fuel wood shortage, but also to arrest land degradation and to combat desertification in arid and semi-arid areas [22].

Since its introduction into eastern Africa, *Prosopis* has been invading natural ecosystems as well as crop- and rangelands with negative effects on the environment and on livelihoods. Thus, dense stands of *Prosopis* are shading the undergrowth, which, combined with the release of allelochemicals, alters the composition and abundance of understory plants, thus negatively affecting native biodiversity [22]. *Prosopis* invasion is often associated with losses of prime agricultural and pastureland as invaded sites often have favorable hydro-edaphic conditions (shallow groundwater and potentially productive Gley-, Fluvi- and Vertisols). The sweet pods are browsed by goats, sheep, cattle and donkeys, potentially causing severe loss of teeth [23]. Despite some benefits such as improved soil fertility [24], soil erosion control, and potentially serving as human food [25], *Prosopis* invasion is generally negatively perceived and widely reported to negatively impact the livelihoods of farmers and pastoralists. Currently, *Prosopis* is declared as a noxious invasive weed in Ethiopia, Kenya, Somaliland, Sudan, Tanzania and in northern Uganda [26]. In Kenya, *Prosopis* is even listed under the "Suppression of Noxious Weeds Act" (CAP-325) [27], targeting its eradication (so far non-successful).

Comprehensive information on the mechanisms of invasion, on socio-ecological impacts, and on effective control measures are an essential starting point, enabling the development of management of *Prosopis*. Overview of these measures and strategies have been provided for the African continent in general [28], and in countries, specifically for Sudan [29], for Ethiopia [30–32] for Somalia [33,34], and for Kenya [35]. However, the effectiveness and large-scale application of suggested strategies in the region is relatively poor, suggesting the need for a niche-specific targeting of intervention strategies. Understanding the management strategies of *Prosopis* and matching them with ecological, social-cultural, and economic needs of the eastern African region is thus a pressing scientific issue. This is of particular relevance in the semi-arid zones where the majority of the most vulnerable communities derive their livelihoods from agriculture and pastoralism.

1.1. Drivers of the Invasive Spread of Prosopis

Plant invasion is thus becoming a defining feature of the Anthropocene [36], and emerging alien species pose a significant challenge to biosecurity in Africa [37] and in provision of ecosystem services [38]. Main drivers of invasion were pinpointed to be closely related to land-use changes [39], to globalization effects [14], and to the emergence of new source pools of seeds and propagules [37]. Continuing expansion of agriculture, increased travel and trade, the development of irrigation and road infrastructures, and climate change have increased the spread of *Prosopis* in eastern Africa [14]. Within approximately 50 years, the shrub has invaded about 12% of the land in the Afar Region of Ethiopia [37] and over 550,000 ha of the land area in Somaliland [33,40]. The invaded area around Lake Baringo in Kenya has increased more than 200-fold between 1988 and 2016 [41]. In South Africa, Ref. [42] estimated that *Prosopis* covered 1.8 million hectares of land in 2017.

Prosopis initially spread from multiple focal points, mainly from original plantation sites, and subsequently invaded the surroundings along corridors for livestock, along river courses and following infrastructure development, acting as dispersal pathways [39,43]. Habitat disturbance due to land-use changes has equally been attributed to rapid invasion of *Prosopis* in many parts of eastern Africa, specifically in the northern parts of the Afar Region [39] and in Baringo and Tana River Counties in Kenya [24]. Flooding events can transport pods and seeds to downstream areas, as reported from the Afar region of Ethiopia and the Tana River Delta in Kenya [19]. Dispersal of diaspores through ingestion by animals and subsequent deposition in their dung (endozoochory) is the most important dispersal mechanism in Baringo, Kenya [44]. Thus, a change in the composition of animal herds (shifts from cattle to goats), following several severe drought periods in the late 1990s and early 2000s, were instrumental for endozoochorous dispersal of seeds and the spread of *Prosopis* in drylands of Kenya [45]. With progressing infrastructure development, mobility of humans and animals, and with pastoralist herds of shifting composition and increasing size, high future invasion rates have been predicted for much of eastern and southern Africa [46].

1.2. Impacts of Prosopis Invasion

Prosopis has a range of positive and negative environmental, social, and economic impacts at various spatial and temporal scales. The negative effects can be categorized into (1) alteration of ecosystems including allelopathic suppression, (2) physical obstruction, (3) competition for resources (space, light, water, nutrients), (4) health effects (physical injury by thorns, cattle poisoning, teeth injury, and as habitat for animal and human disease vectors), and (5) depletion of aquifers through deep root acquisition of water [47]. Positive effects refer to (1) erosion control, (2) soil nutrient elevation (addition of biologically fixed nitrogen, addition of carbon by leaf litter fall, nutrient pumping from subsoil), and (3) ecological benefits (nesting sites for birds, pollen/nectar provision of pollinating insects). However, the negative impacts by far outweigh the positive attributes, with substantial alteration of natural ecosystems and with massive impacts on the livelihood of farmers and pastoralists.

Economic impacts of *Prosopis* range from millions to billions of dollars annually with severe negative ecological and socio-economic impacts [4,5,48]. Ref. [49], observed that *Prosopis* invasion reduced income from livestock and decreased cattle numbers over a ten-year period in Baringo Kenya, while in South Africa, Ref. [11] estimated the costs of managing *Prosopis* invasions at USD 35.5 million per annum.

Herbaceous plants growing under *Prosopis* stands reduced by 27% compared to open (non-invaded) areas within one single year [22]. *Prosopis* invasion in the Ethiopian lowlands led to the loss of some of the most useful grass species in rangelands, mainly the C4 forage grasses *Cenchrus* spp., *Cynodon* spp., *Chrysopogon* spp., *Eragrostis* spp., *Setaria* spp., and *Hyparrhenia* spp. [10]. *Prosopis* has allelopathic characteristics and leaf leachates can negatively affect root growth of crop species [50] and inhibit seed germination and early seedling growth [51]. Other studies have shown *Prosopis* to out-compete native plants by depleting nutrient and water resources [52,53]. *Prosopis* causes injury on humans and animals through pricking by thorns [6,10,54]. Intoxication after *Prosopis* consumption can reportedly cause the fatal nervous disease *Denervation atrophy* in animals in Brazil [55] and Ethiopia [56]. With ingestion of high amounts of *Prosopis* pods, livestock deaths were reported in Botswana [57]. Further, the plant invades grass- and shrub lands, leading to shortage of livestock feed resources as reported from India [58], Ethiopia [59], and Kenya [45].

Despite the negative impacts, *Prosopis* can have important economic benefits, including the provision of fuel, timber, windbreak, and animal fodder [60]. Particularly, charcoal made from *Prosopis* wood has been shown to be profitable at some sites [30,61]. The making of flour for human consumption or of animal feed from pods can contribute to generating income while reducing new invasions by the removal of potentially viable seeds [62,63]. *Prosopis* can have a positive effect on some soil parameters. Thus, *Prosopis* can increase the availability of soil P, the amounts of K, Ca and Mg, possibly by nutrient pumping [59], total soil N by plant nitrate uptake from groundwater, N addition by biological N_2 fixation [49], and organic C from leaf litter fall [41]. Likely, implications of such soil improvement for potential future land uses remain elusive but require further research.

1.3. Management of Prosopis Invasion

The speed of spread and the density in establishment of *Prosopis* also reflects the type and intensity of management practices applied to invaded areas. Efforts have been made globally to manage *Prosopis* through complete eradication, containment, partial control, and utilization, and several studies have evaluated such intervention strategies in tropical and sub-tropical areas, also beyond eastern Africa [64,65].

Most of these studies conclude that management of *Prosopis* requires complete eradication, which is generally expensive and not always effective due to rapid re-sprouting from stems and the soil seedbank. On the other hand, management strategies other than complete eradication may also work in some instances, but need spatial differentiation based on biophysical site attributes and the level of invasion [39]. Further, the efficacy of applied options appears to differ between infested areas, and to depend on the canopy cover of the invaders and the cost of management in relation to benefits incurred [65]. Such reports raise the question of if the studied methods are truly ineffective, or if their effectiveness is rather restricted to specific intensities and types of interventions. In these cases, each management strategy needs to be targeted to its specific niche environment. Such knowledge of "what works where" is currently not available [66]. The identification and definition of specific requirements and of niche-specific management may also include site-specific mechanisms of invasive spread, the community's perception of the problem, social-cultural specifics of land users [67], and the community's ability to mobilize consolidated action at national, regional, or local levels [25].

1.4. Objectives and Aim

The majority of the research carried out on *Prosopis* focuses on vegetation ecology, on the invasion range, and on quantifying impacts, rather than delivering solutions for its management. We surmise that a niche-specific management of *Prosopis* is critical for future control and for tailoring site- and system-specific recommendations at local or regional scales. Consequently, we reviewed the published available empirical research on the management of *Prosopis.* We further analyzed the social-ecological environments where management practices have reportedly contributed to control *Prosopis* spread, while minimizing its negative impacts, with a focus on eastern Africa. We thus addressed the following research questions:

1. To what extent does *Prosopis* infestation affect the choice of its management method?
2. What are the social-ecological determinants of adopting *Prosopis* management strategies/methods?
3. What are the factors affecting, or prerequisites for successful management of *Prosopis*?

To address the first research question, we describe diverse (negative and positive) ecological, economic, and environmental impacts of *Prosopis* based on the sizes and densities of invasions. In the second research question, we relate environmental and socio-cultural attributes that inform the choice of control measures. The third research question defines the range of factors and social-ecological niche requirements for targeting effective management strategies of *Prosopis.* This specific requirement will permeate the definition of what management futures of *Prosopis* are feasible and likely to be adopted under defined social-ecological conditions.

We consider the following terms and definitions:

i. An "impact" is any measurable change in a social, economic, or environmental aspect caused by *Prosopis* invasion, which can be positive, negative, or neutral [68], and may concern humans, animals, or the environment in general [69].
ii. "Management" refers to practices and intervention strategies such as tillage, fire, clear-cut, or exploitation, aimed (among others) at reducing the current cover and the further spread of *Prosopis* by physical, biological, or chemical control measures [70].
iii. "Control" of *Prosopis* is the suppression of its abundance or the reduction of its population size [70].
iv. "Eradication" refers to the complete eliminating of the invasive species and hence arrest its negative environmental impacts [66].
v. "Utilization" is the economic exploitation of *Prosopis* as a means of harnessing their economic potentials for meeting basic human needs [71]. Uses of *Prosopis* reported in this paper include timber, charcoal production, animal feed and flour production, and the exploitation of byproducts (i.e., honey) and ecosystem services (i.e., pollination).
vi. "Containment" aims at arresting the invasive spread of *Prosopis* beyond the zone where it was initially established, i.e., by fencing or the creation of barrier zones.
vii. "Restoration" mainly refers to the reseeding of former pastureland with forage grass species after land clearing from *Prosopis* [72].
viii. "Intensive cropping" refers to exploiting invasion-induced soil fertility by clearing of invaded land and its continuous use for year-round crop cultivation, usually combined with intensive soil tillage and irrigation [24,73].

2. Methods

2.1. Study Region

This research does not involve field studies or primary data collection but constitutes a systematic analysis of previous research and information in peer-reviewed published studies. The study focuses on eastern Africa, namely Kenya, Tanzania, Uganda, Sudan, Somalia, Rwanda, Burundi, Djibouti, Eritrea, and Ethiopia (Figure 1).

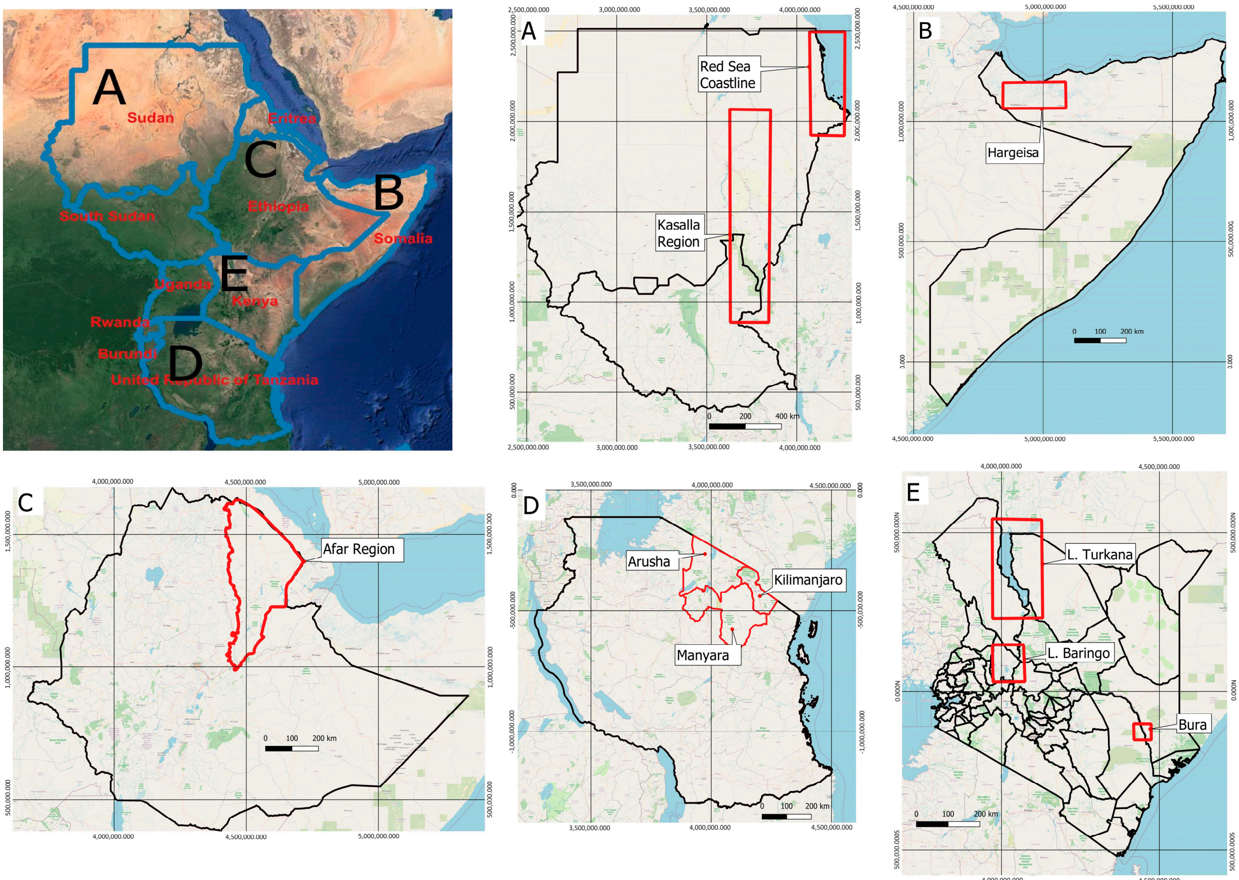

Figure 1. Overview maps showing the eastern Africa countries concerned in the reviewed studies on management strategies of *Prosopis*. The regions marked in red perimeter namely Kasalla in Sudan (**A**); Hargeisa in Somalia (**B**); Afar in Ethiopia (**C**); Arusha, Kilimanjaro, and Manyara in Tanzania (**D**); and Baringo, Turkana, and Bura in Kenya (**E**) are the major areas of *Prosopis* infestation.

2.2. Search Query and Criteria

The search for peer-reviewed literature was conducted using the electronic databases "Science Direct", "Agricola", "CAB Direct", "Scopus" and "Google Scholar", and covered all literature indexed up to 2022. We followed a multistep procedure to compile the relevant publications (Figure 2).

We evaluated empirical studies fulfilling a set of criteria for further analysis, such as (i) the study was conducted in eastern Africa, (ii) it focused on management or control strategies of *Prosopis*, and (iii) papers were published between 1970 and 2022. To avoid bias, the analysis excluded meta-analysis, book chapters, and review papers. The processing of references retrieved followed the "PRISMA" flow diagram [74] presented in Figure 2. In total, five literature search queries were applied hierarchically using the following key words/combinations:

1. "Invasive plant species" and Africa" = 615;
2. "*Prosopis juliflora*" and "Africa" = 538;
3. "Management" and "invasive plant species" and "Africa" = 500;
4. "*Prosopis juliflora*" and "management" and "Africa" = 344;
5. "*Prosopis juliflora*" and "control" and "Africa" = 217.

The initial query provided 1917 hits (published papers) on the topic of alien invasive plants using the five search items. In the first round of reduction, we removed all hits not applying to the research area in Africa, leaving 615 publications. For the second round of reduction, specific search criteria of *Prosopis* in Africa yielded to 538 publications. A further reduction to the search words "*Prosopis*" and "control" or "management" in the abstract, title, or keywords yielded 217 eligible papers. In the final reading and analysis of the full-text publications, we eliminated duplicate publications, review articles, and book chapters, resulting in 53 relevant publications which provided sufficient details in the material and methods sections for answering of research questions of the present analysis. Nine publications reported findings on multiple management options and were evaluated individually for each individual option, leading to 59 studies reported here (Table 1).

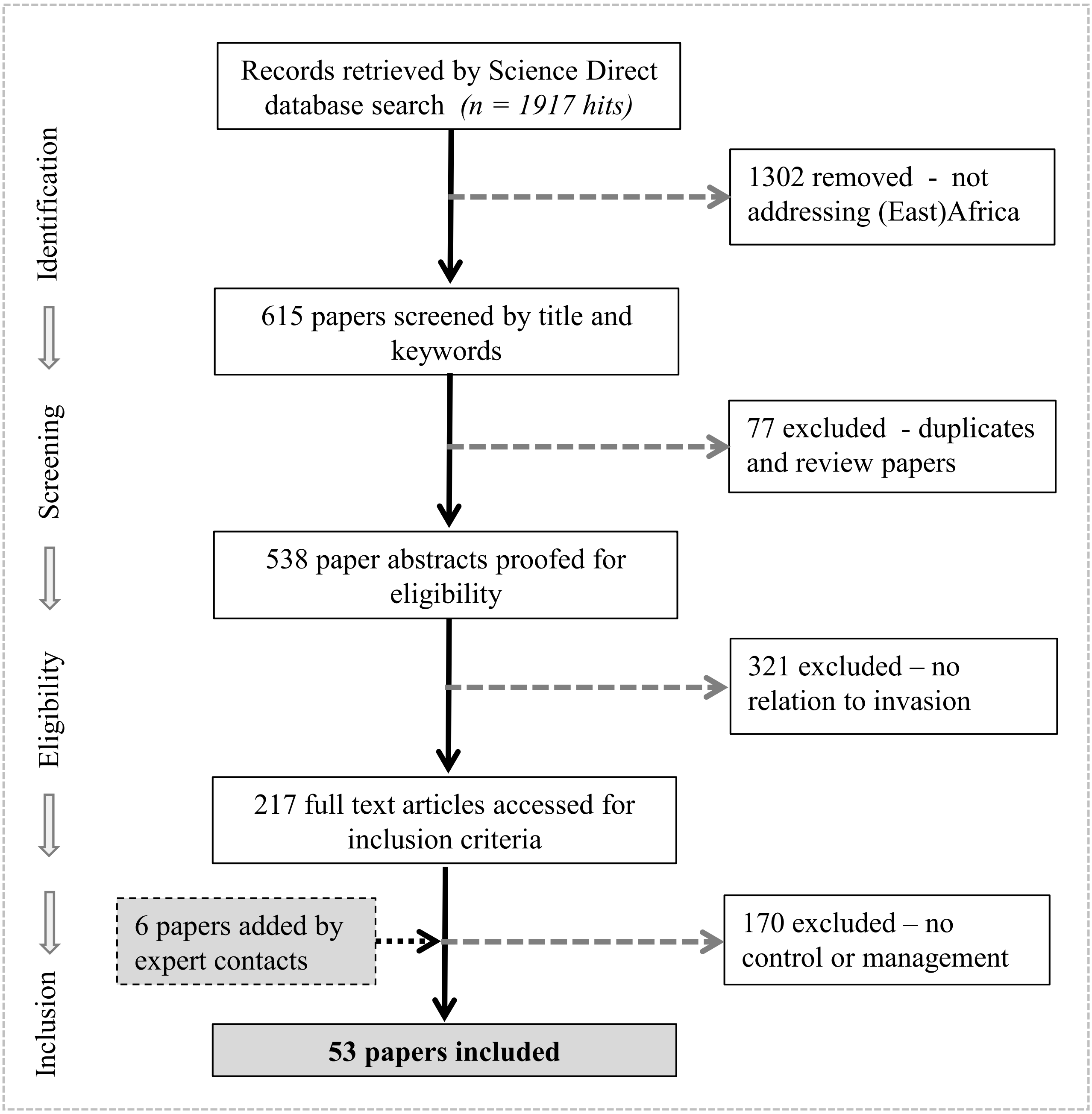

Figure 2. Flow chart detailing the process of screening and identifying references for their eligibility to be included in the systematic review of management of *Prosopis* in eastern Africa. The solid line represents different phases of the systematic review while broken lines represent steps leading to additional or exclusion of papers. (adapted from [74]).

3. Literature Analysis and Synthesis

3.1. Summary Statistics

The following section synthesizes strategies and recommendations for the management of *Prosopis* as reported from empirical studies in eastern Africa. We collated the technical information and classified it according to terms "management", "containment", "utilization", "eradication", and "prevention/mitigation", and assessed the magnitude of their impacts based on available evidence from the target regions. Fifty-three reported studies from five African countries were eligible and thus included in the present analysis (Figure 3). The countries recording the highest numbers of studies were Ethiopia (*n* = 19; 36%), Kenya (*n* = 18; 34%), Sudan (*n* = 7; 13%), Somalia (*n* = 7; 13%), and Tanzania (*n* = 2; 4%). Irrespective of the geographical location, management of *Prosopis* varied from eradication (physical or mechanical removal of isolated target plants), control by mechanical methods (clearing or pruning of young trees and seedling) and biological measures (using insects and other biological agents), containment (reduce size of invasion), land use change (intensive tillage of permanent irrigated land), and utilization (charcoal, fuel, food, honey production) (Table 1).

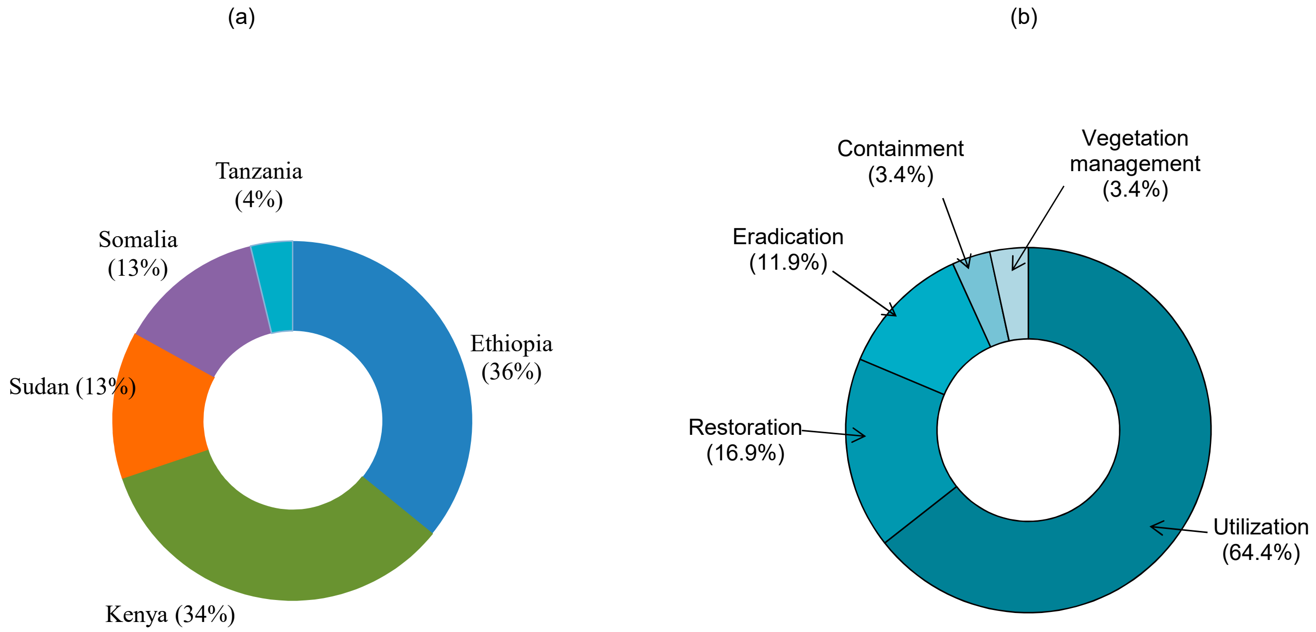

Figure 3. (**a**) Countries in eastern Africa where studies on management of *Prosopis* has been reported (here, share of published papers per country), while (**b**) shows the share of the type of management strategies for *Prosopis* applied in the reported studies (*n* = 59 citations).

Utilization of *Prosopis* was the focus in the majority of the reported case studies (*n* = 38, 64%). The number of studies considering other approaches concerned land restoration (*n* = 10, 17%), containment (*n* = 2, 3%), eradication (*n* = 7, 12%), and vegetation management (*n* = 2, 3%) (Figure 3).

Utilization strategies mainly focused on producing animal feed and human food, harvesting of timber and fuel wood, and charcoal production. *Prosopis* eradication by land conversion to crop or pastureland, involved clear cutting followed by intensive tillage, and (partial) irrigation (Table 1). Studies on land restoration focused on stabilization of sand dunes, restoration of former pastures by over seeding cleared areas with forage species, and the use of *Prosopis* as shelterbelts and fences. In contrast to South Africa [75], chemical and biological measures for vegetation management were rare and have only been reported from Kenya, Sudan, and South Africa.

Table 1. Management strategies of *Prosopis* by country and related references.

Method	Specific	Country	Reference
Containment	Prevention/mitigation	Tanzania Ethiopia	[76] [77]
Eradication	Clear cutting	Ethiopia Sudan	[77–79] [80]
	Pruning	Sudan	[29]
	Uprooting seedlings	Ethiopia	[79,81]
Vegetation management	Biological	Sudan	[82]
	Chemical	Sudan	[82]
Restoration	Dune stabilization	Sudan Somalia	[80] [83]
	Shelter belts	Sudan	[84,85]
	Cropland restoration	Sudan	[81]
	Pasture restoration	Tanzania Kenya	[76,86] [72,87,88]
Intensive cropping	Continuous cultivation (tillage + irrigation)	Ethiopia Kenya	[74] [24]
Utilization	Animal feed	Ethiopia Sudan Kenya	[30,32,58,71,78,79,89] [90,91] [92–94]
	Charcoal	Somalia	[95,96]
		Ethiopia Kenya	[79,97,98] [61,72,99,100]
	Fuel wood	Ethiopia Kenya	[39,71,101,102] [35,61,103,104]
	Human food	Ethiopia Kenya	[30,58,71] [61,105,106]

3.2. Extent of Prosopis Invasion in Eastern African

In the Afar region of Ethiopia, *Prosopis* invaded new areas at an average rate of 3.5 km^2 annually over the period 1973–2004 [79] and has further been predicted to invade at a rate of 31% by 2020 [107]. In Baringo Kenya, [20] reported *Prosopis* coverage having increased from 882 ha in 1988 to nearly 19,000 ha in 2016. This invasion resulted in the loss of grassland (up to 86%), of irrigated cropland (57%), and of rainfed cropland (up to 37%). Apart from Lake Baringo in Kenya and the Afar region in Ethiopia, wetland sites that are starting to be invaded or showing a high likelihood of potential future invasion include the Tana River Delta and the Lorian and Lengurruahanga swamps in Kenya [108], the Awash River basin in Ethiopia, [73,109], and the Tokar River and Gash River Deltas, as well as the Kassala Plains in Sudan [85].

Figure 4 shows the hypothesized sequence of events related to *Prosopis* invasion, following the DPSIR framework of Drivers, Pressures, States, Impacts and Responses [110]. The initial trigger event was the purposeful or accidental introduction of the species into an area. A range of biophysical, infrastructure- or farm management-related factors (Drivers) determine the start and extent of an invasive spread. There are a number of modulating factors in both the political and socio-cultural realm (Pressures) that determine the extent and severity of the consequences of invasion, including the speed and extent of damage caused by *Prosopis* (Impacts). The final impacts on the environment, on resource base quality on human and animal health, and generally on rural livelihood determine the type of response strategies (Responses). The analysis of the publications largely supports the illustrated pathway and emerging response patterns.

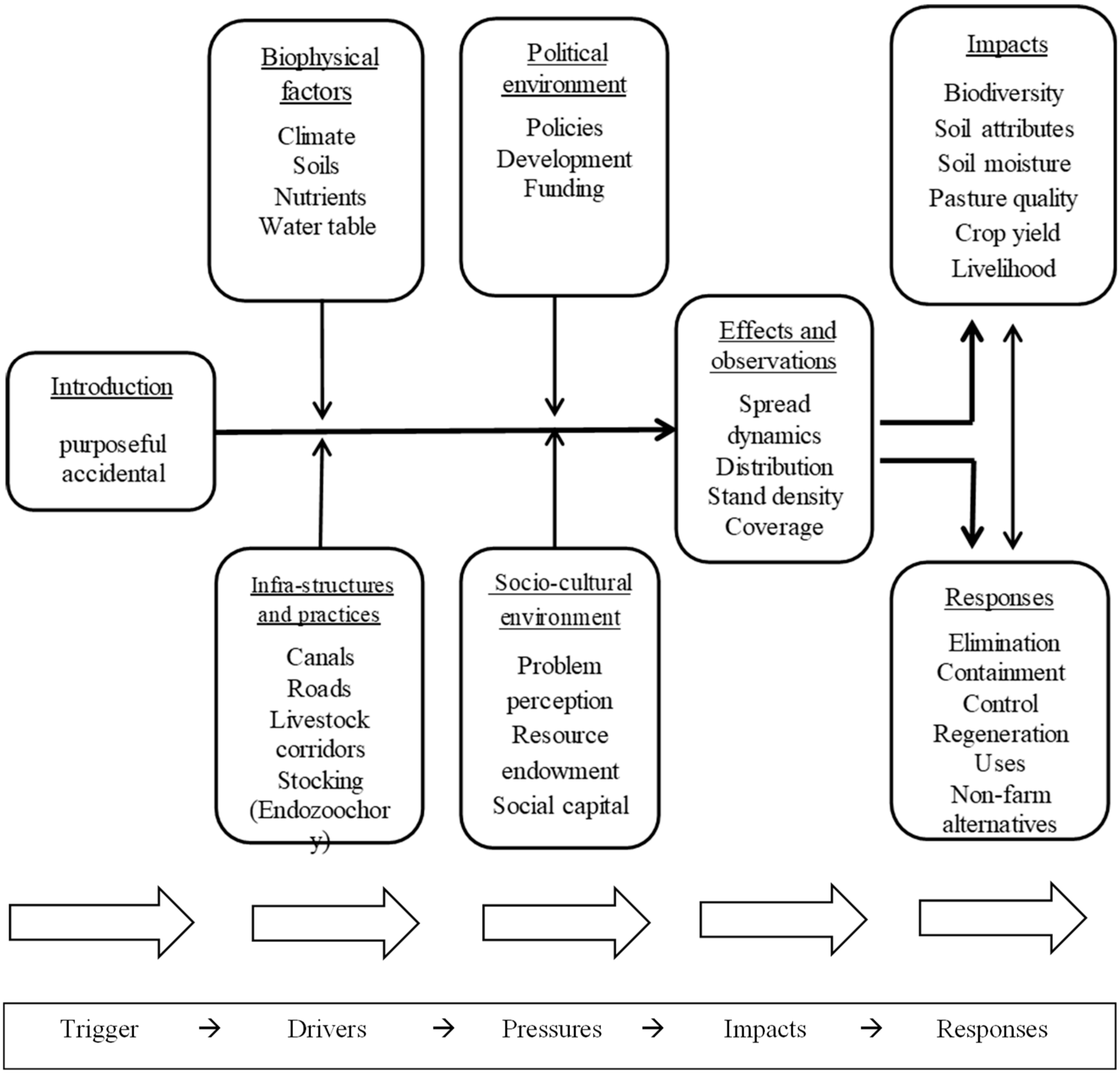

Figure 4. Hypothesized pathways, including drivers and pressures of invasive spread, as well as impacts and response strategies to an invasion by *Prosopis*, following the DPSIR framework [110].

3.3. Impacts of Prosopis Invasion and Their Influence on Response Strategies

Impacts of *Prosopis* in eastern Africa are differentiated by prevailing ecological conditions and by farm household specific attributes as suggested by [111], emphasizing socio-economic drivers and impacts for classifying effects of and responses to alien species [112] (Table 2). Ecological impacts in the reported studies included the suppression of native plant species [59], the degradation of farmland and rangelands [30], erosion control, and an improvement of soil fertility under invasive stands [24]. Studies from Kenya and Ethiopia highlight that most aggressive *Prosopis* invasion and spread dynamics occurred under conditions of the high water table in river floodplains, ravines, swamps, and in the littoral region of freshwater lakes [108].

Table 2. Categories of *Prosopis* impacts based on evidence from the analyzed studies. (√ **indicates positive impact**) (modified after [111]).

Impact	Impact Category	Impact Description	Impact Severity Class			
			Massive	Major	Moderate	Minimal
Ecological	Competition	Competition for water and nutrients-reduced soil moisture and depletion of aquiver water	√	-	-	-
	Biodiversity loss	Competition resulting in extinction of native grass, forage species, indigenous vegetables	√	-	-	-
	Toxicity	Toxicity by ingestion in animals causing nervous disease (*Denervation atrophy* disease)	-	√	-	-
		Produce bio-chemicals that reduce the growth and survival of native plants	-	√	-	-
Ecosystem	Grazing/ herbivory/browsing	Changes in species composition leading to extinction from communities	√	-	-	-
	Chemical, physical, or structural impact on soil	Changes in nutrient pools and nutrient cycling (increase in soil carbon, phosphorus)	-	√	-	-
	Interaction with other species	Canopy negatively affects understory species richness and regeneration	√	-	-	-
	Total ecosystem impact	Alteration of ecosystem functions-loss of forage and grass leading to migration of critical wildlife species, nomadism	-	√	-	-
Livelihood	Economic impacts	Valuable uses including charcoal, fuel wood, construction wood, human and animal feeds	-	√	-	-
	Transmission of diseases-vector ecology	Promotes malaria parasite transmission by *Anopheles* mosquito	-	√	-	-
	Social-cultural	Invasion on fields, drainage channels, foot paths and blockage of roads, affecting of social activities	√	-	-	-

Major impacts on livelihoods concern the blockage of roads, footpaths, animal migration routes, and irrigation canals [113], and the depletion of soil moisture and ground water [109,114] (Table 2).

Prosopis also reportedly affects animal health, including death of livestock, following the ingestion of pods, causing indigestion, tooth decay (due to high sugar content of pods), and decreased livestock productivity [79]. Reported cases of nervous diseases due to the ingestion of *Prosopis* seeds by livestock occurred in both Kenya [56] and Ethiopia [58].

Positive contributions of *Prosopis* to livelihoods relate to provisioning (wood, charcoal, timber, food, and feed) and supporting ecosystem services (erosion control, soil nutrient enrichment, habitat changes, and dune stabilization). Besides *Prosopis* wood being a source of fuel, mature pods can be a valuable source of carbohydrates and proteins for livestock [80], and they can be processed to flour for human consumption. Studies by [41] showed positive relationships between *Prosopis* and soil properties. Thus, dense stands of *Prosopis* are associated with increases in soil carbon pools and increase soil phosphorus contents [73]. It remains a matter of debate if *Prosopis* preferably colonized sites with higher soil fertility, or if dense stands, the absence of soil tillage, subsoil nutrient pumping, and contributions from biologically fixed nitrogen actually improve formerly low soil fertility.

Direct economic impacts are restricted to *Prosopis* use as timber, fuel wood, and charcoal (Table 2). Additional reported benefits concern bee keeping and the production of honey. While these have been extensively studied, the lack of empirical data impedes an analytical classification of the extent of likely benefits of *Prosopis* infestation.

However, such reported benefits are largely counteracted by massive negative impacts. As evidenced by our analysis (Table 2), we can arguably rate the impacts of *Prosopis* invasion in the region as being mainly negative. Such negative impacts are associated with competition between *Prosopis* and native species or crop plants, leading to species displacement or altering of species richness and diversity, and to a depletion of soil moisture stocks and groundwater levels. Apart from the physical obstruction of dense *Prosopis* growth affecting the mobility of humans and animals and reportedly blocking access to watering points, the toxicity of leaves and fresh pods affects animal health. *Prosopis* also alters/improves the habitat for insect vectors of viral diseases [8] and can lead to loss of livelihood and possibly to an outmigration of farmers and pastoralists from infested areas.

3.4. Dimensions of Management of Prosopis

Approaches for the management of *Prosopis* include (1) complete eradication or partial control, (2) utilization of products and ecosystem services provided by *Prosopis*, and (3) the restoration and agricultural uses of invaded land (Table 1), and these are discussed in subsequent sections.

3.4.1. Eradication and Control

Reversing the purposeful or accidental introduction of *Prosopis* and limiting an invasive spread can avoid negative effects on the environment and rural livelihood and comprises three possible options for action: (1) complete eradication, (2) containment, and/or (3) control of land cover and spread of *Prosopis*. The eradication by mechanical methods has been attempted in Ethiopia and Sudan [80] and in Kenya [115]. Applied strategies involved the physical removal of established trees by clear felling, the uprooting of seedlings and young shrubs, and the pruning of older shrubs and trees, or combination of these. Clearing of *Prosopis* using bulldozers and human labor, and burning of uprooted *Prosopis* in farmlands, roadsides, and along irrigation and drainage canals has been reported from several countries. Thus, *Prosopis* was cleared by bulldozers along 36 km of irrigation and drainage canals in Ethiopia from 1995 to 2002. However, use of bulldozers was realized to be expensive (about USD 3600/year in 2002), leading the government to switch to using human labor [116]. In Kenya, mechanical clearing of one hectare of farm or pastureland from *Prosopis* cost approximately USD 2125/ha [6]. All approaches immediately reduced the *Prosopis* cover, but largely failed to eradicate *Prosopis* [80,116] in the longer-term. However, such partial control strategies can contribute to a partial restoration of indigenous vegetation [21].

Ref. [78] showed that slashing and burning of very young *Prosopis* plants was appropriate for controlling and preventing further spread in recently infested areas in semi-arid environments but failed to control spread in humid environments. In addition, the strategy was less effective in mature *Prosopis* stands or in sub-humid environments, where biomass burning was insufficient to prevent the re-sprouting of stumps or to destroy seeds in the soil seed bank. Thus, in the sub-humid Baringo County in Kenya, where *Prosopis* was introduced about 40 years ago, 90% of all affected farmers doubt the longer-term effectiveness of mechanical control strategies, advocating complete eradication of *Prosopis* as the only effective way to reuse their farm or pastureland [115].

A range of chemical control methods, mostly involving the application of Glyphosate, have been applied for managing *Prosopis* in Australia and South Africa, but these are not applicable in the prevailing low-input agricultural systems of eastern Africa, as they require high capital inputs and technical skills. The eradication of *Prosopis* by chemical means is not only expensive but, in many instances, also ineffective—particularly in older stands, as large diaspore and seed banks in the soil ensure a rapid re-infestation of the chemically-cleared areas [101]. In addition, eastern African countries lack both the environmental policies and the institutional capacity to implement such measures [79]. Other methods such as biological control using the leaf-tying moth *Evippe* sp. though effective in the Pilbara region of Western Australia [117], has recently been initiated in South Africa (2021), while Kenya is in the process of testing the biological agent for ultimate release upon approval.

The containment of *Prosopis* at specific sites of interest (fuel wood or timber plantations) or the isolation of infested sites targets avoiding or at least slowing the spread from a center of occurrence [24]. Containment can include the fencing of infested areas to restrict the movement of animals, thus preventing the endozoochorous dispersal of seeds [44]. Alternatively, keeping farm animals in staples, the establishment of livestock kraals; fenced pastures or paddock grazing restrict the movement of farm animals. However, simple fencing or limitations of free grazing movement cannot be stand-alone strategies to contain *Prosopis*. Water flows, wild mammals, and frugivorous birds may also spread seeds and pods beyond the confinement zone, requiring additional management strategies in areas adjacent to the confinement site.

In summary, complete eradication is possible only when *Prosopis* introductions are very recent and established stands are still fairly isolated, while mechanical, chemical, or biological control methods are expensive and require continued interventions. Containment is only effective when combined with other control strategies at the invaded sites.

3.4.2. Utilization

Several authors have recommended the use of *Prosopis* as a potentially valuable resource to support rural livelihoods, while contributing to reduce negative ecological and socioeconomic impacts of invasion. These strategies include a partial removal of *Prosopis* for fuel wood production, charcoal making, timber harvesting, and the use of pods as animal feed or human food [71,91,93]. Additionally, proposed management measures include the thinning of stands to acceptable densities followed by pruning of lower side branches, which enhances bole formation, and the development of tree trunks of good form and structure for industrial timber uses [79,97]. Under this management scenario, *Prosopis* does not form thickets, allowing free movement of animals and people below the canopy and growth of other plants. However, neither the economic feasibility nor large-scale applications of such use strategies have been assessed to date. In addition, it is largely unknown to what extent the use of such methods can be practically sustained to control further invasive spread. As noted by [118], an integrated management approach including inclusion of two to three management options to reduce the spread and impacts of *Prosopis* invasions would be most feasible. Such would include utilization of *Prosopis* products [71,91,92], biological control methods, and use of chemicals.

Strategies of using *Prosopis* for the provision of ecosystem services include soil stabilization and erosion control, increasing feedstuff for pollinating insects such as honeybees, and the greening of desertification-prone areas. Thus, it has been suggested to use *Prosopis* for stabilizing sand dunes [56] or for establishing shelter belts in arid regions to arrest land degradation [58] and contribute to the aims and benefits of the "The Great Green Wall" of Africa (https://www.greatgreenwall.org/about-great-green-wall/) (accessed on 15 September 2022). However, such strategies are likely to be spatially limited by the phreatophyte nature of *Prosopis* and the required presence of a shallow groundwater table. In addition, purposeful introductions of *Prosopis* for afforestation, as barriers to land degradation and for provision of other ecosystem services, are a double-edged sword as introduction sites can act as potential starting points of future invasion. However, management by utilization could create a dependency on the invasive species with some sections of the community benefiting economically [63,119] and thus encouraging the spread, while others preferring to control it [69].

3.4.3. Restoration by Cultivation

A most promising strategy involves the mechanical removal of *Prosopis* and a subsequent conversion of formerly invaded lands into intensive and permanently cultivated cropland. Supplementary irrigation permits an expansion of crop uses into the dry season, while regular mechanical tillage and the use of herbicides prevent an invasive spread of *Prosopis* [61]. In most reported cases, cultivation focuses on growing of maize during the wet season and various (irrigated) vegetables (mainly mung bean–*Vigna radiata* and watermelon–*Cucumis melo*) in the dry season. Crops benefit from the soil quality improvement under long-term *Prosopis* occupation (soil recovery in the absence of tillage and biomass removal and soil enrichment with nutrients by leaf litter fall). However, the large investments in infrastructure for irrigation, the availability of water for irrigation and the access to output markets is likely to restrict this approach to a limited number of sites. Thus, in the Perkerra irrigation scheme in Baringo, the Kenyan government has provided the initial infrastructure development, including the construction of system of canals for irrigation and the establishment of a market for the commercialization of high-value products (including maize hybrid seeds). Similarly, in the New Halfa Scheme in Northern Sudan, the government invested in the development of an irrigation scheme in 2008, permitting a conversion of invaded rainfed pastureland into irrigated cropland [80]. Consequently, the success of converting formerly infested land areas into cropland is closely linked (1) to initial state investments in infrastructure, (2) to economic benefits derived from the commercialization of high-value (perishable) crops on rehabilitated land, as well as (3) to supportive legal instruments to prevent *Prosopis* re-invasion [120].

Other related rehabilitation strategies concern a (partial) removal of *Prosopis* from former pastureland and the re-seeding of cleared areas with fast-growing pasture species for hay production and commercialization [88]. While this strategy can temporarily reduce the invasive spread of *Prosopis* longer-term benefits are likely to require regular control of *Prosopis* regrowth.

3.5. Summary and Knowledge Gaps in Management of Prosopis

Table 3 summarizes some major knowledge gaps concerning *Prosopis* in eastern Africa identified during synthesis of literature. While social-ecological drivers and ecological impacts of *Prosopis* spread have been extensively researched, risk modeling and prediction of areas with likely future spread will help define future intervention zones for early control strategies [43,121]. Most importantly, the effectiveness of applied management strategies and their likely adoption by concerned communities differ strongly between sites. Consequently, the application of management strategies and the definition of extrapolation of specific target domains are required for effectively managing *Prosopis* in already affected, and to prevent infestation and damage of likely future infection sites across the region and beyond.

Table 3. Knowledge gaps regarding pathways and impacts of invasion, management strategies, and research output requirements for *Prosopis control* in eastern Africa.

Research Area	Gaps
Invasion pathways	• Unequal research and knowledge across diverse ecosystems • Mechanisms underlying *Prosopis* spread at different sites • Site specific drivers of invasive spread
Impacts	• Data on agricultural losses and environmental costs of invasion • Risk analysis of future evolution of invasive spread • Consequences and economic impacts of *Prosopis* invasions
Control and management	• On-farm resource availability and prioritization for effective resource allocation • Site-specific cost effectiveness of control strategies • Policies and guidelines for management of invasions • Assessment tools for the prevention of future *Prosopis* invasion • Social-ecological niches and extrapolation domains of control strategies
Research outputs	• Information sharing, education and awareness among communities and regions lacking • Integrating social, ecological and economic for management decisions

3.6. Specific Requirements for Targeting Management Strategies

The effectiveness of and benefits derived from various management strategies vary widely between the reported papers and study sites. Differences appear to be related to spatial scales, to biophysical site attributes, to cultural/livelihood factors, and to socio-economic attributes of households and communities [111,112]. While knowledge of the ecology of *Prosopis* is required to support and inform management interventions [4,122], the control of *Prosopis* can probably not be reduced by single management measures but may require combinations of approaches aimed at different goals [57,63] (Table 4). Thus, wider consideration of effectiveness and an effective targeting of measures require the definition of social-ecological niche environments and possibly a wider stakeholder engagement [123].

Table 4. *Prosopis* management strategies, goals and aims, and social-ecological niche requirements for their adoption.

***Prosopis* Control and Management Strategy**				**Management Requirements**		
Strategy	**Goal**	**Management**	**Specific Aim**	**Biophysical Needs**	**Resource Requirements**	**Organizational Needs**
Containment	Avoiding invasion into new sites	Fencing of timber and fuel wood lots	Restrict spread of seeds and pods	Low invasion range; Dry environments	Capital and labor for fence establishment	Manage conflicting interests; lot owners vs. pastoralists
		Limit endozoochorous seed spread	Avoid free-ranging animal movements	Year-round availability of feed resources	Improved pasture management and animal stabulation	Knowledge on sedentary pasture management
		Uprooting of young seedlings in periphery	Establish "clean" buffer zone	Early wet season; Light-textured soils	Labor for clearing in buffer zones	Awareness of conflicting interests; community action
Eradication	Clear cutting or chemical elimination	Uprooting young seedlings	"Clean" rangelands	Light textured soils; Early wet season	High initial labor	Coordinated individual or community action
		Pruning and burning of middle-old stands	Avoid seed setting	Dry season	Labor and knowledge on effective burning	Regular monitoring of re-invasion
		Chemical control	Kill seeds and biomass	Avoid water source areas and ecological sensitive sites	Availability of herbicides, capital and knowledge	Awareness of risks; environmental management plan
		Clearing of old stands by heavy machinery	Eliminate biomass and diaspores	None	Capital and heavy equipment	Cooperatives for joint ownership of expensive machinery
Control	Limit invasion to manageable level	Mechanical control	Reduce stand densities	None	Labor or machinery	Community action
		Chemical control	Reduce stand densities	Dry season	Capital, effective herbicides, knowledge	Environmental management plan
		Biological control	Reduce stand densities	Absence of host plants other than *Prosopis*	Knowledge, available control agents	Knowledge on potential risks

Table 4. *Cont.*

Prosopis Control and Management Strategy				Management Requirements		
Strategy	**Goal**	**Management**	**Specific Aim**	**Biophysical Needs**	**Resource Requirements**	**Organizational Needs**
Utilization	Consumption	Animal feed	Provision of hay and pod meal	Dry conditions permitting harvest and drying of pods	Ruminant numbers	Policies and regulations on processing standards
		Human food	Manufacture pod-based flour	Dry conditions permitting harvest and drying of pods	Technology for pod processing	Awareness: Policies on processing standards
	Fuel and timber	Charcoal	Generate income from coal trade	Dry conditions to establish traditional kilns	None	Law and regulations allowing regional trade
		Fuelwood	Generate income to meet own fuel needs	Old *Prosopis* stands	Labor and machinery	Laws for regional trade; investment in wood power plants
		Timber	Maximize usable wood production	Old *Prosopis* stands	Land ownership; Labor for pruning	Research on tree management and timber uses
Restoration	Cropland restoration	Clearing	Permanent crop cultivation	None	High labor and capital	Coordinated action, land investments for machinery ownership
		Tillage	Regular clearing of *Prosopis* re-growth	None	Implements and machinery	Financial support; Credit
		Irrigation	Water provision for dry season cultivation	Access to water	Investments in canals and pumps; Market access	Public support for establishing infrastructure
	Pastureland restoration	Clearing rainfed land	Year-round forage production	None	Labor and machinery	Coordinated action, land ownership
		Over-seeding		Early wet season	Availability of quality seeds; market demand for hay	Support for seed provision; support for transport and trade
		Regular cutting of hay		Sufficient soil moisture in dry season		Coordinated action, land ownership
	Ecological restoration	Erosion control	Permanent soil cover	Soil moisture availability	Land ownership Awareness	Coordinated community action
		Shelter belts and dune stabilization	Vegetation barriers	Shallow groundwater	Labor, Knowledge	Payment for ecosystem services

The aim of any management program of invasive species is to reduce the range and density of invasions and therefore control negative economic, social, and environmental impacts of the invasive species [66]. Biophysical site attributes and prevailing land use and agronomic practices determine not only the type and intensity of invasion [45], but also the effectiveness of control measures [78]. Social differentiation determines (1) how communities understand or interpret the consequences of plant invasion and (2) associated preferences for management interventions [122]. Thus, preferences for management interventions differ by age, gender, location, values, and livelihood [124]. *Prosopis* management should therefore be site-specific, goal-specific, and culturally sensitive, and it must account for both technology-specific requirements and household-specific endowment with resources (land, labor, capital, and knowhow) and for land users' adaptive capacity to implement control measures. In addition, social-political requirements and livelihood needs of households and communities may differ between land users such as semi-nomadic or sedentary pastoralists, agro-pastoralists, and crop farmers. Depending on the intensity of invasion and land users' capacity to take action against *Prosopis*, the specific management strategies will thus differ in terms of temporal and spatial scales, and by social-ecological attributes (Table 4). The following sections address this niche-specificity for the main management strategies.

3.6.1. Specific Requirements for Containment of *Prosopis* Spread

As a phreatophyte, *Prosopis* requires "wet places" with shallow groundwater, water flows, and high soil moisture availability [45]. It will not spread into dryland areas with deep water tables, and containment strategies are thus required only within the wetland sites where they aim at avoiding or at least slowing the invasive spread from a center of occurrence [24]. Containment can include the fencing of infested areas and restricting movement of animals, usually in combination with control measures at the periphery of the containment sites. Fencing off infested sites or woodlots for timber and fuel production can contribute to minimizing endozoochorous seed spread, but it requires initial investments to which woodlot owners may not see the benefits. Similarly, containing animals in stables, paddocks, or fenced grazing lots requires initial investments and "new" knowledge of sedentary animal production, rarely practiced by East African agro-pastoralist who mostly use free-range grazing or semi-nomadic migration strategies. The additionally required control of young *Prosopis* plants in the periphery of containment lots requires early interventions during wet periods in humid environments [81], or the uprooting and burning of biomass in semi-arid environments during the dry season [78]. Consequently, requirements for effective containment of *Prosopis* are limited and highly site specific. Required initial investments are capital intensive, while both sedentary animal rearing and land management systems are knowledge intensive. Improved awareness and training of stakeholders may expand the currently limited social-ecological niche environments for a successful containment of *Prosopis.*

3.6.2. Specific Requirements for Eradication and Control of *Prosopis*

The eradication or long-term population reduction of old or well-established *Prosopis* stands is difficult to achieve [38,125], and it usually requires large investments in manual labor, machinery, or chemical products [126]. In such "old" stands and in very large invasion-affected areas, a combination of partial eradication in conjunction with restorative habitat management (i.e., establishing conservancies) may become a realistic recourse [63]. However, to be economically attractive, eradication should target recently invaded sites with very young *Prosopis* plants (no seed formation, cheap clearing), and strategies must be linked to other (economical) management goals such as producing charcoal or establishing crops or improved pastures. This is also relevant in view of complete eradication to negatively affect the environment by increased wind speed, evaporative water losses, and soil erosion [79]. In summary, eradication strategies are likely to work best in semi-arid regions, in rather confined or smaller wetlands, in areas with low livestock densities, and in well-organized communities able to apply cooperative action.

3.6.3. Specific Requirement for Utilization of *Prosopis*

With negative impacts on the quality of their resource base [48], associated losses in livelihoods [49], and poor successes in containment and eradication of *Prosopis* [81,125], households are compelled to derive a living from their *Prosopis*-infested land. As part of the effort to identify solutions for poverty alleviation, responsible uses of *Prosopis* may thus be a crucial strategic option [24]. Besides the production and sale of honey, the main direct use strategies refer to timber and firewood, to charcoal making and trade, and to the use of the sweet pods by transforming them into animal feed and human food.

Prosopis cultivation and management in woodlots for timber production is limited by high management demands for regular pruning in view of obtaining straight stems, and by poor wood quality in older individuals due to hallow trunks. However, with regular pruning, trees can reportedly yield more than six times larger usable wood volume compared to unmanaged stands, thus obtaining higher market prices for construction wood [29].

The production and use of charcoal is most prominent among reported use strategies, and most widely researched in terms of production practices, trade, and economic benefits. Charcoal production requires low initial investments, uses traditional production methods, and usually has a ready market in most areas of East Africa. Despite being prohibited in Afar, Ethiopia [127] and only selectively approved in Baringo, Kenya, land users increasingly pursue charcoal production, investing USD 38 US/year in Baringo, Kenya and USD 50/year in the Afar region of Ethiopia. Benefits from charcoal production and trade can be large, reaching up to USD 150/week in Somaliland [128]. Consequently, at most infested sites of the region, charcoal is considered a viable management option for both small-scale producers [129] and for commercially-oriented, larger-scale producer groups such as the Charcoal Producer Associations (CPAs) in Baringo, Kenya [61]. Accordingly, the benefits derived from the use of *Prosopis* (charcoal and food) were higher (USD 231 million) than the costs of controlling infestation (USD 116 million) in a case study from Ethiopia [130]. Thus, charcoal burners in Gewane (Ethiopia) consider *Prosopis* to be their "black gold" through charcoal production and trade, and they resist so far efforts of complete eradication [119].

On the other hand, selected *Prosopis* eradication with subsequent crop uses is reportedly even more profitable and less risky than charcoal-making [30], though [69] argues that it is inadvisable to base a management program on income generation for one single sector of the community. The ban on logging and restrictions on transportation and sale, especially in Kenya, may further discourage intense use of *Prosopis* products, timber, food and feed, as well as charcoal [61]. In addition, the (frequently rather modest) economic benefits derived from *Prosopis* uses may slow down efforts to control or even eradicate *Prosopis*. This is a concern of pastoralists and agro-pastoralists in the Afar community of Ethiopia, to whom the negative impacts by far outweigh financial advantages to a small share of the community using *Prosopis* products. In addition, the costs of reclaiming and restoring invaded lands for pasture and crop uses tend to be lower than the long-term financial and environmental costs of allowing *Prosopis* to spread unchecked and its utilization for charcoal or animal feed [127].

The processing of *Prosopis* pods for human food and livestock feeds was assessed and refined to suit local needs in Kenya and Ethiopia [61]. However, the lack of awareness of such potential uses and benefits prevents pastoralists from utilizing the shrub as a feed source for livestock, while flour making for human consumption is still at the experimental stage. At present, the production of flour for human use appears to be both risky and largely unprofitable [10]. Information sharing, education and awareness-creation, and validation of economically viable technologies are required [73]). Training community beneficiaries on utilization, and basic maintenance of production equipment could have the multiplier effect required to enhance such *Prosopis* uses in the wider region [131]. However, in the absence of harmonized government policies [61,127], it is unlikely that people or communities will invest in *Prosopis* uses.

All utilization strategies of *Prosopis* products require older and well-established stands, while eradication and control strategies for pasture and crop uses are most effective in young stands or in recently invaded areas. Old *Prosopis* stands act as starting points for spread and invasion of adjacent land areas, and it is hence undesired in pastoral, agro-pastoral or crop farming communities. Such conflicting demands can hardly be reconciled and bear a high potential for conflicts between concerned interest groups.

Requirements for implementing longer-term *Prosopis* utilization strategies are thus restricted to areas and communities with no interests in pasture and crop uses, and none of the nine invaded study sites reported on in this review are fulfilling this precondition.

3.6.4. Specific Requirements for Land Restoration for Crop and Pasture Uses

Generating income from agriculture in formerly invaded land involves a complete removal of *Prosopis* and the reclaiming of the cleared land for permanent year-round cultivation of either (partially irrigated) food, horticultural or industrial crops or of re-seeding and the commercial production of pasture grasses. Such land use intensification requires high initial investment in the clearing of stands, in infrastructure, access to markets and an advanced level of agronomic knowledge, which is likely to be an impediment in remote rural sites and in pastoral communities of eastern Africa [125].

In parts of Baringo, Kenya, *Prosopis* infested areas are recommended to be cleared for intensive commercial horticultural production [105]. Intensive mechanical tillage operations and regular and weed control within the crops largely eliminate *Prosopis* from agricultural land, provided that fallow periods are avoided. Such dry season fallows in rainfed cropland permit the re-sprouting and re-establishment of *Prosopis* [61]. In Ethiopia, the conversion of *Prosopis*-infested land to irrigated cotton has been shown to be highly profitable, with a net present value (NPV) of USD 5234 /ha over 10 years [30]. The authors concluded that utilization and restorative land conversion with intensive cropping constitutes a viable *Prosopis* management strategy, if water is available for irrigating dry season crops, and provided that (former pastoral) land users are knowledgeable in soil and crop management. The latter requirement often fails to be met in strictly pastoralist communities.

Pasture reseeding of formerly invaded and selectively cleared grazing areas with African foxtail grass (*Cenchrus ciliaris*) has been implemented in Kenya, both on an individual basis and through the organization of communities and cooperatives. These interventions have provided fodder banks, feedlots, and grass seed for sale, generating incomes for households and communities [132]. However, high labor requirements for clearing and uprooting *Prosopis* stumps, the availability and cost of grass seeds, and a rapid regeneration of *Prosopis* from the soil seed bank were identified as key challenges in these restored pasture systems [87,120].

3.6.5. Cross Cutting *Prosopis* Management Requirements

The level of impact and the knowledge of *Prosopis* invasion pathways and the adaptive capacity of individuals and communities to respond in a timely manner to invasions and policy frameworks are key determinants for successfully implementing management decisions

1. *Prosopis* is mainly spread by livestock, leading to dispersal of seeds up to more than 100 km in a week in pastoral areas [133]. Because *Prosopis* seeds can persist for long periods in the seed bank [97] and coppices vigorously regrow after tree harvest [134], pruning and charcoal making may not suffice to control *Prosopis* unless other follow-up interventions are implemented.
2. Containment may be improved through surveying and mapping early invasions by targeting likely extrapolation domains of intervention sites, by restricting animal movement in invaded areas and by awareness creation [76].
3. Social involvement in the management of *Prosopis* is required. Pastoralists prefer complete eradication, sedentary small-scale agro-pastoralists favor use strategies, while larger-scale farmers aim for eradication followed by intensive (irrigated) crop cultivation [32,77]. Because of the high demand for labor (or for capital when using heavy machinery), community commitment and participation are needed for successful *Prosopis* management. Thus, involvement of community leadership was found to be most efficient in implementing charcoal producer associations [61,73,135].
4. Harmonized national strategies on *Prosopis* management and policies can guide and reconcile the aims of land users and other stakeholders. However, none of the countries concerned in this analysis have effective regulations, institutional ar-

rangements, or policies in place to manage *Prosopis* invasions. The implementation of strategies has been hindered by fragmentation and conflicting of stakeholder interests. Thus, Ethiopia's National Strategy on *Prosopis* management [116] aims to prevent the expansion of *Prosopis* to so far non-invaded areas; the government of Somalia advocates mechanical eradication of *Prosopis* in its National Development Plan 2012–2016 [136,137] and Kenya's National Strategy and Action Plan for control of *Prosopis* focuses on utilization strategies [61,138].

5. Managing of conflicts arising from the invasion of *Prosopis* is desirable for effective planning and management. Initial introductions of *Prosopis* in the region was aimed for afforestation and rehabilitation of degraded land and therefore eradication of the *Prosopis* is always viewed by conservationists as destruction of the environment [139]. Further, Ref. [140] showed that conflicts of interest attributed to social cultural setting such as values and beliefs and level of community awareness could affect management of alien plant species. Such was the case in Ethiopia where [119] reported that agro-pastoral communities wanted to clear *Prosopis* infested areas to increase crop land while charcoal burners wanted to burn charcoal for sale. This created differences among the communities due to perceived benefits of *Prosopis* invasion [118] which then creates a unique niche requirement for effective management of *Prosopis.*
6. Sharing of information and the integration of social, ecological, biophysical and economic data will aid site- and system-specific management and assist in taking appropriate management decisions. The new Kenyan Strategy and Action Plan for control of *Prosopis* may provide a window of opportunities for such cross-border activities and harmonized policies between Tanzania, Ethiopia, South Sudan, and Somalia. Further, development of region-specific guidelines and consensus on management initiatives would equally contribute to *Prosopis* management. Such guidelines can be entrenched in national programs to restore and protect ecosystems advocated by African Union.

4. Conclusions

The target of the UN Sustainable Development Goal 15 is to reduce the impact of invasive alien species on land and water ecosystems and to control or eradicate priority species (SDG 15: 8). Our literature analyses showed that short- to long-term strategies for the management of *Prosopis* must be targeted to specific biophysical environments and systems of management and socio-economic and cultural attributes based on the invasion range and magnitude, the perceived, actual impacts of invasion, and the adaptive capacity of individuals and communities to successfully implement such strategies. The following conclusions are derived from the present study:

1. The extent, intensity and impact of the invasive spread of *Prosopis* differ by country and climatic zone, affected site, and prevailing land management (pastures vs. croplands), with the shallow groundwater table as an ecological prerequisite for vigorous *Prosopis* growth.
2. Effective management and control of *Prosopis* requires a combination of methods that may include mechanical clearing and uprooting and/or burning the rootstock, chemical clearing of vegetation, processing, and utilization of biomass (charcoal or timber), and active land use and management, i.e., for crop production.
3. The effectiveness and applicability of specific control strategies depend on the biophysical environment, on household-specific resource endowment and farmers' adaptive capacity, and on the level of political/institutional support.
4. The first priority should be to avoid the introduction of invasive species by carrying out the required measures of prevention. Where invaders are spreading, they must be eradicated at early stages through a process of early detection and rapid response. When *Prosopis* is well established, integrated methods or combinations of management and utilization strategies may be applied.

5. Active land use systems (such as crop cultivation through irrigation and pasture development) are among the most effective methods of managing *Prosopis* invasions. However, traditional pastoral communities rarely practice intensive agricultural land use systems and often lack the required technical knowledge. While such shifts in land use from pastoralism to sedentary crop farming constitute the economically most promising way forward, the strategy may be limited by high initial investment costs, poor access to produce markets, and high demands on technical knowledge is an addition to constituting a drastic change in cultural lifestyle for pastoral communities.
6. Competing economic interests among user groups, community members, and government agencies limit the combined applicability of management and use strategies. There is a need for a participatory development of a National Strategy and Action Plan that considers, reconciles, and regulates competing interests. Interventions must safeguard livelihood benefits while mitigating negative impacts on the environment and other sectors of the economy.
7. Awareness creation, capacity building through training, and the establishment of appropriate community frameworks and governance structures to manage invasions can help reduce negative effects brought about by the uncontrolled spread of invasive species.
8. More research is required to assess and predict future invasion, to plan and execute prevention and early detection and rapid response measures. Such approaches could include in situ quantification and monitoring trials to detect spread [141] and controlled experimental trials for biological control of *Prosopis* [142]. In addition, there is a need for proper understanding of social-ecological niches and extrapolation domains for targeting intervention measures is needed.

Author Contributions: Conceptualization, M.B. and H.W.K.; writing—original draft preparation, H.W.K.; writing—review and editing, H.W.K., M.B. and S.K.C.; validation of content, M.B. and S.K.C. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the German Research Association (DFG) in the framework of the Collaborative Research Center "Future Rural Africa https://www.crc228.de/projects/", accessed on 15 June 2021.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Pyšek, P.; Hulme, P.E.; Simberloff, D.; Bacher, S.; Blackburn, T.M.; Carlton, J.T.; Richardson, D.M. Scientists' warning on invasive alien species. *Biol. Rev.* **2020**, *95*, 1511–1534. [CrossRef] [PubMed]
2. Rouget, M.; Robertson, M.P.; Wilson, J.R.; Hui, C.; Essl, F.; Renteria, J.L.; Richardson, D.M. Invasion debt–quantifying future biological invasions. *Divers. Distrib.* **2016**, *22*, 445–456. [CrossRef]
3. Seebens, H.; Bacher, S.; Blackburn, T.M.; Capinha, C.; Dawson, W.; Dullinger, S.; Genovesi, P.; Hulme, P.E.; van Kleunen, M.; Kühn, I.; et al. Projecting the continental accumulation of alien species through to 2050. *Glob. Chang. Biol.* **2021**, *27*, 970–982. [CrossRef] [PubMed]
4. Shackleton, R.T.; Le Maitre, D.C.; Van Wilgen, B.W.; Richardson, D.M. The impact of invasive alien *Prosopis* species (mesquite) on native plants in different environments in South Africa. *S. Afr. J. Bot.* **2015**, *97*, 25–31. [CrossRef]
5. Shackleton, R.T.; Le Maitre, D.C.; van Wilgen, B.W.; Richardson, D.M. Use of non-timber forest products from invasive alien *Prosopis* species (mesquite) and native trees in South Africa: Implications for management. *For. Ecosyst.* **2015**, *2*, 16. [CrossRef]
6. Maundu, P.; Kibet, S.; Morimoto, Y.; Imbumi, M.; Adeka, R. Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods. *Biodiversity* **2009**, *10*, 33–50. [CrossRef]
7. Hussain, M.I.; Shackleton, R.T.; El-Keblawy, A.; Del Mar Trigo Pérez, M.; González, L. Invasive Mesquite (*Prosopis juliflora*), an allergy and health challenge. *Plants* **2020**, *9*, 141. [CrossRef] [PubMed]
8. Agha, S.B.; Alvarez, M.; Becker, M.; Fèvre, E.M.; Junglen, S.; Borgemeister, C. Invasive alien plants in Africa and the potential emergence of mosquito-borne arboviral diseases—A review and research outlook. *Viruses* **2020**, *13*, 32. [CrossRef] [PubMed]
9. GISD. Global Invasive Species Database. 2017. Available online: www.issg.org/database (accessed on 20 June 2021).
10. Wakie, T.T.; Laituri, M.; Evangelista, P.H. Assessing the distribution and impacts of *Prosopis juliflora* through participatory approaches. *Appl. Geogr.* **2016**, *66*, 132–143. [CrossRef]

11. Wise, R.M.; Van Wilgen, B.W.; Le Maitre, D.C. Costs, benefits and management options for an invasive alien tree species: The case of mesquite in the Northern Cape, South Africa. *J. Arid. Environ.* **2012**, *84*, 80–90. [CrossRef]
12. Pasiecznik, N.; Enterprises, A. Information on Measures and Related Costs in Relation to Species Considered for Inclusion on the Union List: Prosopis juliflora. Technical Note Prepared by IUCN for the European Commission. 2018. Available online: https://circabc.europa.eu/sd/a/30b8a728-06b9-401f-a940-9531636e8fe9/TSSR%20Task%202018%20Prosopis%20juliflora.pdf (accessed on 21 June 2021).
13. Lowe, S.; Browne, M.; Boudjelas, S.; De Poorter, M. *100 of the World's Worst Invasive Alien Species: A Selection from the Global Invasive Species Database*; Invasive Species Specialist Group (ISSG) Auckland: Auckland, New Zealand, 2000; Volume 12, p. 12. Available online: www.issg.org/booklet.pdf (accessed on 21 June 2021).
14. Pasha, S.V.; Reddy, C.S. Global spatial distribution of Prosopis juliflora-one of the world's worst 100 invasive alien species under changing climate using multiple machine learning models. *Environ. Monit. Assess.* **2024**, *196*, 196. [CrossRef] [PubMed]
15. Kulkarni, S.; Surange, S.; Shekhar Nautiyal, C. Crossing the limits of Rhizobium existence in extreme conditions. *Curr. Microbiol.* **2000**, *41*, 402–409. [CrossRef] [PubMed]
16. Puppo, M.C.; Felker, P. (Eds.) *Prosopis as Heat-Tolerant Nitrogen-fixing Desert Food Legume: Prospects for Economic Development in Arid Lands*; Academic Press: London, UK, 2021; ISBN 9780128233207.
17. Verdoodt, A.; Mureithi, S.M.; Van Ranst, E. Impacts of management and enclosure age on recovery of the herbaceous rangeland vegetation in semi-arid Kenya. *J. Arid. Environ.* **2010**, *74*, 1066–1073. [CrossRef]
18. Abebe, T. Growth performance of some multipurpose trees and shrubs in the semi-arid areas of Southern Ethiopia. *Agrofor. Syst.* **1994**, *26*, 237–248. [CrossRef]
19. Mworia, J.K.; Kinyamario, J.I.; Omari, J.K.; Wambua, J.K. Patterns of seed dispersal and establishment of the invader *Prosopis juliflora* in the upper floodplain of Tana River, Kenya. *Afr. J. Range Forage Sci.* **2011**, *28*, 35–41. [CrossRef]
20. ElFadl, M.A. Management of *Prosopis juliflora* for Use in Agroforestry Systems in the Sudan. Ph.D. Thesis, University of Helsinki, Helsinki, Finland, 1997.
21. van Klinken, R.D.; Hoffmannm, J.H.; Zimmermann, H.G.; Roberts, A.P.; Muniappan, R. Prosopis species (Leguminosae). In *Biological Control of Tropical Weeds Using Arthropods*; Muniappan, R., Reddy, G.V., Raman, A., Eds.; Cambridge University Press: Cambridge, UK, 2009; pp. 353–377.
22. Kahi, H.C.; Ngugi, R.K.; Mureithi, S.M.; Ng'ethe, J.C. The canopy effects of *Prosopis juliflora* (dc.) and *Acacia tortilis* (Hayne) trees on herbaceous plants species and soil physico-chemical properties in Njemps flats, Kenya. *Trop. Subtrop. Agroecosyst.* **2009**, *10*, 441–449.
23. Mutavi, S.K. Effects of Prosopis juliflora pod and leaf meal on physical characteristics of teeth and bones of goats in Kitui County, Kenya. *Livest. Res. Rural. Dev.* **2020**, *32*, 163.
24. Mbaabu, P.R.; Ng, W.T.; Schaffner, U.; Gichaba, M.; Olago, D.; Choge, S.; Oriaso, S.; Eckert, S. Spatial evolution of Prosopis invasion and its effects on LULC and livelihoods in Baringo, Kenya. *Remote Sens.* **2019**, *11*, 1217. [CrossRef]
25. Pasiecznik, N.; Livingstone, J.; Shibeshi, A.; Ahmed, S.; Fre, Z. Utilization of *Prosopis juliflora* in the Horn of Africa: Recent developments. In *Prosopis as a Heat-Tolerant Nitrogen-Fixing Desert Food Legume*; Academic Press: London, UK, 2022; pp. 169–185. ISBN 9780128233207. [CrossRef]
26. CABI. Invasive Species Compendium Online Data Sheet. In *Prosopis juliflora (Mesquite)*; CABI Publishing: Oxfordshire, UK, 2015. Available online: www.cabi.org/ISC (accessed on 22 June 2022).
27. The Kenya Gazette. *The Suppression of Noxious Weeds Act*; Gazette Notice No. 184; The Kenya Gazette: Nairobi, Kenya, 9 January 2009; p. 50.
28. Patnaik, P.; Abbasi, T.; Abbasi, S.A. *Prosopis* (*Prosopis juliflora*): Blessing and bane. *Trop. Ecol.* **2017**, *58*, 455–483.
29. Elfadl, M.A.; Luukkanen, O. Effect of pruning on *Prosopis juliflora: Considerations* for tropical dryland agroforestry. *J. Arid. Environ.* **2003**, *53*, 441–455. [CrossRef]
30. Wakie, T.T.; Hoag, D.; Evangelista, P.H.; Luizza, M.; Laituri, M. Is control through utilization a cost effective *Prosopis juliflora* management strategy? *J. Environ. Manag.* **2016**, *168*, 74–86. [CrossRef] [PubMed]
31. Müller-Mahn, D.; Rettberg, S.; Getachew, G. Pathways and dead ends of pastoral development among the Afar and Karrayu in Ethiopia. *Eur. J. Dev. Res.* **2010**, *22*, 660–677. [CrossRef]
32. Ayanu, Y.; Jentsch, A.; Müller-Mahn, D.; Rettberg, S.; Romankiewicz, C.; Koellner, T. Ecosystem engineer unleashed: *Prosopis juliflora* threatening ecosystem services? *Reg. Environ. Chang.* **2015**, *15*, 155–167. [CrossRef]
33. Rembold, F.; Leonardi, U.; Ng, W.T.; Gadain, H.; Meroni, M.; Atzberger, C. Mapping areas invaded by *Prosopis juliflora* in Somaliland on Landsat 8 imagery. *Remote Sens. Agric. Ecosyst. Hydrol.* **2015**, *9637*, 295–306. [CrossRef]
34. Meroni, M.; Ng, W.T.; Rembold, F.; Leonardi, U.; Atzberger, C.; Gadain, H.; Shaiye, M. Mapping *Prosopis juliflora* in west Somaliland with Landsat 8 satellite imagery and ground information. *Land Degrad. Dev.* **2017**, *28*, 494–506. [CrossRef]
35. Choge, S.; Muthike, G. Experiences of managing *Prosopis juliflora* invasions by communities in Kenya: Challenges and Opportunities. In *Managing Prosopis juliflora for Better (Agro-) Pastoral Livelihoods in the Horn of Africa, Proceedings of the Regional Conference, Addis Ababa, Ethiopia, 1–2 May 2014*; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Bonn/Eschborn, Germany, 2014; pp. 93–103.
36. Lewis, S.L.; Maslin, M.A. Defining the Anthropocene. *Nature* **2015**, *519*, 171–180. [CrossRef] [PubMed]

37. Seebens, H.; Blackburn, T.M.; Dyer, E.E.; Genovesi, P.; Hulme, P.E.; Jeschke, J.M.; Pagad, S.; Pyšek, P.; van Kleunen, M.; Winter, M.; et al. Global rise in emerging alien species results from increased accessibility of new source pools. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, E2264–E2273. [CrossRef] [PubMed]
38. Vilà, M.; Ibáñez, I. Plant invasions in the landscape. *Landsc. Ecol.* **2011**, *26*, 461–472. [CrossRef]
39. Essl, F.; Lenzner, B.; Bacher, S.; Bailey, S.; Capinha, C.; Daehler, C.; Dullinger, S.; Genovesi, P.; Hui, C.; Hulme, P.E.; et al. Drivers of future alien species impacts: An expert-based assessment. *Glob. Chang. Biol.* **2020**, *26*, 4880–4893. [CrossRef]
40. Awale, A.I.; Sugule, A.J. Proliferation of Honey Mesquite (*Prosopis juliflora*) in Somaliland. In *Opportunities and Challenges Case Study*; Candle Light for Health, Education and Environment: Abu Dhabi, United Arab Emirates, 2006; Available online: https://www.candlelightsomal.org/wp-content/uploads/2014/07/proliferation-of-Prosopis-juliflora-in-Somaliland.pdf (accessed on 22 June 2022).
41. Mbaabu, P.R.; Schaffner, U.; Eckert, S. Invasion of Savannas by *Prosopis* Trees in Eastern Africa: Exploring Their Impacts on Lulc Dynamics, Livelihoods and Implications on Soil Organic Carbon Stocks. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2021**, *43*, 335–340. [CrossRef]
42. Zachariades, C.; Paterson, I.D.; Strathie, L.W.; Van Wilgen, B.W.; Hill, M.P. Assessing the status of biological control as a management tool for suppression of invasive alien plants in South Africa. *Bothalia-Afr. Biodivers. Conserv.* **2017**, *47*, 1–19. [CrossRef]
43. Abbas, A.M.; Soliman, W.S.; Mansour, A.; Taher, E.; Hassan, I.N.; Mahmoud, M.; Abdelkareem, M. Predicting the spatial spread of invasive *Prosopis juliflora* (SW.) DC along environmental gradients in Gabel Elba National Park, Egypt. *Int. J. Sci. Eng. Res.* **2016**, *7*, 596–599.
44. Alvarez, M.; Leparmarai, P.; Heller, G.; Becker, M. Recovery and germination of *Prosopis juliflora* (Sw.) DC. seeds after ingestion by goats and cattle. *Arid. Land Res. Manag.* **2017**, *31*, 71–80. [CrossRef]
45. Becker, M.; Alvarez, M.; Heller, G.; Leparmarai, P.; Maina, D.; Malombe, I.; Bollig, M.; Vehrs, H. Land-use changes and the invasion dynamics of shrubs in Baringo. *J. East. Afr. Stud.* **2016**, *10*, 111–129. [CrossRef]
46. Sintayehu, D.W.; Egeru, A.; Ng, W.T.; Cherenet, E. Regional dynamics in distribution of *Prosopis juliflora* under predicted climate change in Africa. *Trop. Ecol.* **2020**, *61*, 437–445. [CrossRef]
47. Alredaisy, S.M. Ecological Impacts of Mesquite '*Prosopis* spp.' Expansion in Delta Toker Agricultural Scheme, Northeastern Sudan. In Proceedings of the 1st International Conference on Humanities and Educational Studies, Graduate College, University of Khartoum, Khartoum, Sudan, February 2013.
48. van Wilgen, B.W.; Wannenburgh, A.; Foxcroft, L.C. The extent and effectiveness of alien plant control projects in South Africa. In *Biological Invasions in South Africa*; Van Wilgen, B., Measey, J., Richardson, D.M., Wilson, J., Zengeya, T.A., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 597–628. [CrossRef]
49. Linders, T.E.; Bekele, K.; Schaffner, U.; Allan, E.; Alamirew, T.; Choge, S.K.; Eckert, S.; Haji, J.; Muturi, G.; Mbaabu, P.R.; et al. The impact of invasive species on social-ecological systems: Relating supply and use of selected provisioning ecosystem services. *Ecosyst. Serv.* **2020**, *41*, 101055. [CrossRef]
50. Noor, M.; Salam, U.; Khan, M.A. Allelopathic effects of *Prosopis juliflora* (Swartz DC). *J. Arid. Environ.* **1995**, *31*, 83–90. [CrossRef]
51. Getachew, S.; Demissew, S.; Woldemariam, T. Allelopathic effects of the invasive *Prosopis juliflora* (Sw.) DC on selected native plant species in Middle Awash, Southern Afar Rift of Ethiopia. *Manag. Biol. Invasions* **2012**, *3*, 105–114. [CrossRef]
52. Bibi, S.; Bibi, A.; Al-Ghouti, M.A.; Abu-Dieyeh, M.H. Allelopathic Effects of the Invasive *Prosopis juliflora* (Sw.) DC. on Native Plants: Perspectives toward Agrosystems. *Agronomy* **2023**, *13*, 590. [CrossRef]
53. Dzikiti, S.; Schachtschneider, K.; Naiken, V.; Gush, M.; Moses, G.; Le Maitre, D.C. Water relations and the effects of clearing invasive *Prosopis* trees on groundwater in an arid environment in the Northern Cape, South Africa. *J. Arid. Environ.* **2013**, *90*, 103–113. [CrossRef]
54. Mwangi, E.; Swallow, B. *Prosopis juliflora* invasion and rural livelihoods in the Lake Baringo area of Kenya. *Conserv. Soc.* **2008**, *6*, 130–140. [CrossRef]
55. Tabosa, I.M.; Riet-Correa, F.; Barro, S.S.; Summers, B.A.; Simões, S.V.D.; Medeiros, R.M.T.; Nobre, V.M.T. Neurohistologic and ultrastructural lesions in cattle experimentally intoxicated with the plant *Prosopis juliflora*. *Vet. Pathol.* **2006**, *43*, 695–701. [CrossRef] [PubMed]
56. Admasu, D. *Invasive Plants and Food Security: The Case of Prosopis juliflora in the Afar Region of Ethiopia, FARM-Africa*; IUCN: Gland, Switzerland, 2008; pp. 1–3. Available online: http://cmsdata.iucn.org/downloads/invasive_plants_and_food_security_final.pdf (accessed on 22 June 2022).
57. Mosweu, S.; Munyati, C.; Kabanda, T.; Setshogo, M.; Muzila, M. *Prosopis* L. invasion in the south-western region of Botswana: The perceptions of rural communities and management options. *Nat. Resour.* **2013**, *4*, 496–505. [CrossRef]
58. Wakie, T.T.; Evangelista, P.; Laituri, M. *Utilization Assessment of Prosopis juliflora in Afar Region, Ethiopia*; US Forest Service, USDA Office of International Programs, USAID Pastoral Livelihoods Initiative II Project (PLI II) Colorado State University: Fort Collins, CO, USA, 2012; pp. 1–15.
59. Kaur, R.; Gonzales, W.L.; Llambi, L.D.; Soriano, P.J.; Callaway, R.M.; Rout, M.E.; Gallaher, T.J. Community impacts of *Prosopis juliflora* invasion: Biogeographic and congeneric comparisons. *PLoS ONE* **2012**, *7*, e44966. [CrossRef] [PubMed]
60. Bayliss, H.; Stewart, G.; Wilcox, A.; Randall, N. A perceived gap between invasive species research and stakeholder priorities. *NeoBiota* **2013**, *19*, 67–82. [CrossRef]

61. Choge, S.; Mbaabu, P.R.; Muturi, G.M. Management and control of the invasive *Prosopis juliflora* tree species in Africa with a focus on Kenya. In *Prosopis as a Heat-Tolerant Nitrogen-Fixing Desert Food Legume*; Academic Press: London, UK, 2022; pp. 67–81. [CrossRef]
62. Syomiti, M.; Hoag, H.; Getachew, G.; Beatrice, M.; Wamae, D. Medicated *Prosopis* spp-based feed blocks-for anthelmintic efficacy and performance of weaner lambs. *Livest. Res. Rural. Dev.* **2015**, *27*, 50.
63. Abdulahi, M.M.; Ute, J.A.; Regasa, T. *Prosopis juliflora* L: Distribution, impacts and available control methods in Ethiopia. *Trop. Subtrop. Agroecosyst.* **2017**, *20*, 75–89. [CrossRef]
64. Pandey, C.B.; Singh, A.K.; Saha, D.; Mathur, B.K.; Tewari, J.C.; Kumar, M.; Goyal, R.K.; Mathur, M.; Gaur, M.K. *Prosopis juliflora* (Swartz) DC.: An invasive alien in community grazing lands and its control through utilization in the Indian Thar Desert. *Arid. Land Res. Manag.* **2019**, *33*, 427–448. [CrossRef]
65. Shackleton, R.T.; Le Maitre, D.C.; Pasiecznik, N.M.; Richardson, D.M. *Prosopis*: A global assessment of the biogeography, benefits, impacts and management of one of the world's worst woody invasive plant taxa. *AoB Plants* **2014**, *6*, plu027. [CrossRef] [PubMed]
66. García-Díaz, P.; Cassey, P.; Norbury, G.; Lambin, X.; Montti, L.; Pizarro, J.C.; Powell, P.A.; Burslem, D.F.; Cava, M.; Damasceno, G.; et al. Management policies for invasive alien species: Addressing the impacts rather than the species. *BioScience* **2021**, *71*, 174–185. [CrossRef]
67. Mbaabu, P.R.; Olago, D.; Gichaba, M.; Eckert, S.; Eschen, R.; Oriaso, S.; Choge, S.K.; Linders, T.E.; Schaffner, U. Restoration of degraded grasslands, but not invasion by Prosopis juliflora, avoids trade-offs between climate change mitigation and other ecosystem services. *Sci. Rep.* **2020**, *10*, 20391. [CrossRef]
68. Barney, J.N.; Tekiela, D.R.; Dollete, E.S.; Tomasek, B.J. What is the "real" impact of invasive plant species? *Front. Ecol. Environ.* **2013**, *11*, 322–329. [CrossRef] [PubMed]
69. Tye, A. *Guidelines for Invasive Species Planning and Management on Islands*; International Union for Conservation of Nature: Gland, Switzerland, 2018. [CrossRef]
70. Wittenberg, R.; Cock, M.J. (Eds.) *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices*; CAB International: Oxford, UK, 2001; Volume xvii, p. 228.
71. Tessema, Y.A. Ecological and economic dimensions of the paradoxical invasive species-*Prosopis juliflora* and policy challenges in Ethiopia. *J. Econ. Sustain. Dev.* **2012**, *3*, 62–70.
72. Chengole, J.M.; Welimo, M.; Belmin, R.; Ng'ang'a, T.; Kamau, G. From a desired to a despised and later desired tree: The case of *Prosopis* introduction and management in Marigat, Baringo County, Kenya. In Proceedings of the International Workshop on Agricultural Innovation Systems in Africa (AISA), Nairobi, Kenya, 29–31 May 2013; French Agricultural Research Centre for International Development (CIRAD): Montpelliers, France, 2014; pp. 75–78. Available online: https://wocatpedia.net/images/4/4b/052015_Proceedings_regional_conference_on_Prosopis_juliflora,_Addis_Abeba.pdf#page=94 (accessed on 5 January 2022).
73. Ilukor, J.; Rettberg, S.; Treydte, A.; Birner, R. To eradicate or not to eradicate? Recommendations on *Prosopis juliflora* management in Afar, Ethiopia, from an interdisciplinary perspective. *Pastoralism* **2016**, *6*, 1–8. [CrossRef]
74. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Ann. Intern. Med.* **2009**, *151*, 264–269. [CrossRef] [PubMed]
75. Zimmermann, H.G.; Hoffmann, J.H.; Witt, A.B.R. A South African perspective on *Prosopis*. *Biocontrol News Inf.* **2006**, *27*, 6–9.
76. Kilawe, C.J.; Mbwambo, J.R.; Kajembe, G.C.; Mwakalukwa, E.E. Mrashia: Prosopis Has Started Invading Pastures and Agricultural Lands in Tanzania. The Woody Weeds Project 2017. Available online: https://www.woodyweeds.org (accessed on 5 January 2023).
77. Tilahun, M.; Birner, R.; Ilukor, J. Household-level preferences for mitigation of *Prosopis juliflora* invasion in the Afar region of Ethiopia: A contingent valuation. *J. Environ. Plan. Manag.* **2017**, *60*, 282–308. [CrossRef]
78. Berhanu, A.; Tesfaye, G. The *Prosopis* dilemma, impacts on dryland biodiversity and some controlling methods. *J. Drylands* **2006**, *1*, 158–164. [CrossRef]
79. Haregeweyn, N.; Tsunekawa, A.; Tsubo, M.; Meshesha, D.; Melkie, A. Analysis of the invasion rate, impacts and control measures of *Prosopis juliflora*: A case study of Amibara District, Eastern Ethiopia. *Environ. Monit. Assess.* **2013**, *185*, 7527–7542. [CrossRef]
80. Network, S.I. *Controlling and/or Using Prosopis juliflora in Spate Irrigation Systems*; Practical Note no. 25.; Spate Irrigation Network: Khartoum, Sudan, 2014; Volume 24.
81. Ahmed, T.E. Mesquite in Sudan: A boon or bane for drylands? It's socioeconomic and management aspects in Kassala State, Sudan. *J. For. Prod. Ind.* **2014**, *3*, 182–190.
82. Kool, M.; Mohamed, Y.A.; Nzumira, H. Controlling and/or using *Prosopis juliflora* in Spate Irrigation Systems. In *Managing Prosopis juliflora for Better (Agro-) Pastoral Livelihoods in the Horn of Africa, Proceedings of the Regional Conference, Addis Ababa, Ethiopia, 1–2 May 2014*; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Bonn/Eschborn, Germany, 2014; Volume 9, pp. 73–85.
83. Zollner, D. Sand dune stabilization in Central Somalia. *For. Ecol. Manag.* **1986**, *16*, 223–232. [CrossRef]
84. Bristow, S.; Sahel, S.O.S. *Prosopis juliflora* for Irrigated Shelterbelts in Arid Conditions in Northern Sudan. *Prosopis, 13.* In *Prosopis: Semi-Arid Fuel Wood and Forage Tree, Building Consensus for the Disenfranchised. a Workshop, 13–15 March 1996*; Felker, P., Moss, J., Eds.; U.S. National Academy of Sciences Building: Washington, DC, USA, 1996; pp. 245–263.
85. Hoshino, B.; Karamalla, A.; Abd Elbasit, M.A.; Manayeva, K.; Yoda, K.; Suliman, M.; Elgamri, M.; Nawata, H.; Yasuda, H. Evaluating the invasion strategic of Mesquite (*Prosopis juliflora)* in eastern Sudan using remotely sensed technique. *J. Arid. Land Stud.* **2012**, *22*, 1–4.

86. Jumanne, Y.; Moyo, F.; Mbwambo, J.R. Effects of Restoration Techniques on Plant Diversity and Forage Biomass in Areas Invaded by *Prosopis juliflora*. *Int. J. Adv. Sci. Res. Eng.* **2021**, *7*, 9–15. [CrossRef]
87. Eschen, R.; Bekele, K.; Mbaabu, P.R.; Kilawe, C.J.; Eckert, S. *Prosopis juliflora* management and grassland restoration in Baringo County, Kenya: Opportunities for soil carbon sequestration and local livelihoods. *J. Appl. Ecol.* **2021**, *58*, 1302–1313. [CrossRef]
88. Rotich, I.T. Progressive Effects of *Prosopis juliflora* (Swartz D.C.) on Grazing Natural Pasture and Browse Plants in Baringo County, Kenya. Ph.D. Thesis, University of Nairobi, Nairobi, Kenya, 2016.
89. Sawal, R.K.; Ratan, R.; Yadav, S.B.S. Mesquite (*Prosopis juliflora*) pods as a feed resource for livestock—A review. *Asian-Australas. J. Anim. Sci.* **2004**, *17*, 719–725. [CrossRef]
90. Abedelnoor, T.; Talib, N.H.; Mabrouk, A.A.; Mohamed, M.A.; El-Mahi, M.I.; Abu-Eisa, H.H.; Bokrezion, H. *The Use of Alternative Animal Feeds to Enhance Food Security and Environmental Protection in the Sudan (The Case for Prosopis juliflora)*; PENHA-APRC: Khartoum, Sudan, 2009; Available online: www.penhanetwork (accessed on 12 January 2023).
91. Eldaw, M.Y. Nutritional Value of Mesquite *(Prosopis juliflora)* Pods and Dietary Effects on Physiological Performance of Sudanese Nubian Goat Kids. Ph.D. Thesis, Sudan University of Science and Technology, Khartoum, Sudan, 2016.
92. Abdulrazak, S.A.; Awano, T.; Ichinohe, T.; Fujihara, T.; Nyangaga, J. Nutritive evaluation of *Prosopis juliflora* fruits and leaves from Kenya: Chemical composition and *in-vitro* gas production. *Proc. Br. Soc. Anim. Sci.* **1999**, *1999*, 146. [CrossRef]
93. Koech, O.K.; Kinuthia, R.N.; Wahome, R.G.; Choge, S.K. Effects of *Prosopis juliflora* seedpod meal supplement on weight gain of weaner Galla goats in Kenya. *Res. J. Anim. Sci.* **2010**, *4*, 58–62. [CrossRef]
94. Muteng'e, M.S. Evaluation of Cactus *(Opuntia ficus indica)* and *Prosopis juliflora* as Potential Supplementary Feed Resources for Livestock in Drought-Prone Areas of Kenya. Ph.D. Thesis, Egerton University, Njoro, Kenya, 2021.
95. Livingstone, J.; Abdi, K.; Shibeshi, A. *The Management and Utilization of Prosopis juliflora*; Policy Workshop Report; FMNR Hub: Hargeisa, Somaliland, 2014.
96. BORESHA (Building Opportunities for Resilience in the Horn of Africa). *From 'Unwanted' and 'Unknown' to Alternative Source of Livelihood Community Management of the Invasive Prosopis Plant*; Technical Brief No. 2; BORESHA Consortium-Danish Refugee Council-East Africa and Great Lakes: Nairobi, Kenya, 2020; Available online: https://resilience.igad.int/wp-content/uploads/2020/06/BORESHA-Prosopis-TB.pdf (accessed on 10 October 2022).
97. Pasiecznik, N.M.; Felker, P.; Harris, P.J.; Harsh, L.; Cruz, G.; Tewari, J.C.; Cadoret, K.; Maldonado, L.J. *The Prosopis juliflora—Prosopis pallida Complex: A Monograph*; HDRA: Coventry, UK, 2001; Volume 172.
98. Kiflie, Z.; Solomon, M.; Kassahun, S.K. Statistically optimized charcoal production from *Prosopis juliflora* for use as alternative fuel in cement factories. *Biomass Convers. Biorefinery* **2021**, *13*, 1539–1552. [CrossRef]
99. Zeila, A. Mapping and Managing the Spread of *Prosopis juliflora* in Garissa County, Kenya. Ph.D. Thesis, Kenyatta University, Nairobi, Kenya, 2011.
100. Oduor, N.; Githiomi, J.K. Fuel-wood energy properties of *Prosopis juliflora* and *Prosopis* pallida grown in Baringo District, Kenya. *Afr. J. Agric. Res.* **2013**, *8*, 2476–2481.
101. Sertse, D.; Pasiecznik, N.M. *Controlling the Spread of Prosopis juliflora in Ethiopia by Its Utilization*; HDRA: Coventry, UK, 2005; Available online: https://www.hdra.org.uk (accessed on 21 June 2021).
102. Tilahun, S.L.; Asfaw, A. Modeling the expansion of *Prosopis juliflora* and determining its optimum utilization rate to control its invasion in Afar Regional State of Ethiopia. *Int. J. Appl. Math. Res.* **2012**, *1*, 726–743. [CrossRef]
103. Sirmah, P.; Muisu, F.; Mburu, F.; Dumarçay, S.; Gérardin, P. Evaluation of *Prosopis* juliflora properties as an alternative to wood shortage in Kenya. *Bois Forêts Trop.* **2008**, *298*, 25–35.
104. Huho, J.M.; Omar, M.H. *Prosopis juliflora* in Asals of Kenya: A friend or a foe plant. *Int. J. Sci. Res. Publ.* **2020**, *10*, 9968. [CrossRef]
105. Choge, S.K.; Pasiecznik, N.M.; Harvey, M.; Wright, J.; Awan, S.Z.; Harris, P.J.C. *Prosopis* pods as human food, with special reference to Kenya. *Water SA* **2007**, *33*, 419–424. [CrossRef]
106. Shitanda, D.; Mukonyi, K.; Kagiri, M.; Gichua, M.; Simiyu, L. Properties of *Prosopis juliflora* and its potential uses in ASAL areas of Kenya. *J. Agric. Sci. Technol.* **2013**, *15*, 15–27.
107. Shiferaw, H.; Schaffner, U.; Bewket, W.; Alamirew, T.; Zeleke, G.; Teketay, D.; Eckert, S. Modelling the current fractional cover of an invasive alien plant and drivers of its invasion in a dryland ecosystem. *Sci. Rep.* **2019**, *9*, 1576. [CrossRef]
108. Muturi, G.M.; Poorter, L.; Mohren, G.M.J.; Kigomo, B.N. Ecological impact of *Prosopis* species invasion in Turkwel riverine forest, Kenya. *J. Arid. Environ.* **2013**, *92*, 89–97. [CrossRef]
109. Shiferaw, H.; Alamirew, T.; Dzikiti, S.; Bewket, W.; Zeleke, G.; Schaffner, U. Water use of *Prosopis juliflora* and its impacts on catchment water budget and rural livelihoods in Afar Region, Ethiopia. *Sci. Rep.* **2021**, *11*, 2688. [CrossRef]
110. Smeets, E.; Weterings, R. *Environmental Indicators: Typology and Overview*; Technical Report No 25; TNO Centre for Strategy, Technology and Policy: Hague, The Netherlands, 1999; p. 19.
111. Blackburn, T.M.; Essl, F.; Evans, T.; Hulme, P.E.; Jeschke, J.M.; Kühn, I.; Kumschick, S.; Marková, Z.; Mrugała, A.; Nentwig, W.; et al. A unified classification of alien species based on the magnitude of their environmental impacts. *PLoS Biol.* **2014**, *12*, e1001850. [CrossRef]
112. Bacher, S.; Blackburn, T.M.; Essl, F.; Genovesi, P.; Heikkilä, J.; Jeschke, J.M.; Jones, G.; Keller, R.; Kenis, M.; Kueffer, C.; et al. Socio-economic impact classification of alien taxa (SEICAT). *Methods Ecol. Evol.* **2018**, *9*, 159–168. [CrossRef]
113. Geesing, D.; Al-Khawlani, M.; Abba, M.L. Management of introduced *Prosopis* species: Can economic exploitation control an invasive species. *Unasylva* **2004**, *217*, 36–44.

114. Coppock, D.; Aboud, A.; Kisoyan, P.K. *Agro-Pastoralists' Wrath for the Prosopis Tree: The Case of the Il Chamus of Baringo District, Kenya*; Research Brief 05-02-PARIMA; Global Livestock Collaborative Research Support Program; University of California Davis: Davis, CA, USA, 2005; Available online: https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1196&context=envs_facpub (accessed on 21 June 2021).
115. Mwangi, E.; Swallow, B. *Invasion of Prosopis juliflora and Local Livelihoods: Case Study from the Lake Baringo Area of Kenya*; World Agroforestry Centre: Nairobi, Kenya, 2005; pp. 1–68.
116. Government of Ethiopia (GoE). *National Strategy on Prosopis juliflora Management*; Ministry of Livestock and Fisheries: Addis Ababa, Ethiopia, 2017; p. 38. Available online: http://www.celep.info/wp%E2%80%93content/uploads/2017/02/Ethiopia%E2%80%93Prosopis-Strategy.pdf (accessed on 12 October 2022).
117. Saleh, I.A.; BiBi, A.; Bibi, S.; Abu-Dieyeh, M.; Al-Ghouti, M.A. Waste-to-value: Guidelines for the potential applications of *Prosopis juliflora*. *Bioresour. Technol. Rep.* **2023**, *24*, 101678. [CrossRef]
118. Shackleton, R.T.; Le Maitre, D.C.; van Wilgen, B.W.; Richardson, D.M. Towards a national strategy to optimise the management of a widespread invasive tree (Prosopis species; mesquite) in South Africa. *Ecosyst. Serv.* **2017**, *1*, 242–252. [CrossRef]
119. Feleke, S.; Haile, F.; Genene, D.; Yadeta, G.; Tolessa, A.; Tantu, T.; Alemu, T.; Bekalu, Y. Production and characterization of charcoal briquette from oxytenanthera abyssinica, arundinaria alpina, Acacia melifera and Prosopis juliflora. *J. Sci. Innov. Res.* **2020**, *9*, 16–21. [CrossRef]
120. Tebboth, M.G.L.; Few, R.; Assen, M.; Degefu, M.A. Valuing local perspectives on invasive species management: Moving beyond the ecosystem service-disservice dichotomy. *Ecosyst. Serv.* **2020**, *42*, 101068. [CrossRef]
121. Eckert, S.; Hamad, A.; Kilawe, C.; Linders, T.E.; Ng, W.T.; Mbaabu, P.R.; Shiferaw, H.; Witt, A.; Schaffner, U. Niche change analysis as a tool to inform management of two invasive species in Eastern Africa. *Ecosphere* **2020**, *11*, e02987. [CrossRef]
122. Ricciardi, A.; Iacarella, J.C.; Aldridge, D.C.; Blackburn, T.M.; Carlton, J.T.; Catford, J.A.; Dick, J.T.; Hulme, P.E.; Jeschke, J.M.; Liebhold, A.M.; et al. Four priority areas to advance invasion science in the face of rapid environmental change. *Environ. Rev.* **2021**, *29*, 119–141. [CrossRef]
123. Tabe Ojong, M.P.; Alvarez, M.; Ihli, H.J.; Becker, M.; Heckelei, T. Action on invasive species: Control strategies of *Parthenium hysterophorus* L. on smallholder farms in Kenya. *Environ. Manag.* **2022**, *69*, 861–870. [CrossRef] [PubMed]
124. Belnap, J.Y.; Ludwig, J.A.; Wilcox, B.P.; Betancourt, J.L.; Dean, W.R.J.; Hoffmann, B.D.; Milton, S.J. Introduced and invasive species in novel rangeland ecosystems: Friends or foes? *Rangel. Ecol. Manag.* **2012**, *65*, 569–578. [CrossRef]
125. Tabe-Ojong, M.P. Action against invasive species: Charcoal production, beekeeping, and *Prosopis* eradication in Kenya. *Ecol. Econ.* **2023**, *203*, 107614. [CrossRef]
126. Bekele, K.; Haji, J.; Legesse, B.; Schaffner, U. Economic impacts of *Prosopis* spp. invasions on dryland ecosystem services in Ethiopia and Kenya: Evidence from choice experimental data. *J. Arid. Environ.* **2018**, *158*, 9–18. [CrossRef]
127. Shibeshi, A.; Livingstone, J.; Pasiecznik, N. *Turning Invasive Garaanwa (Prosopis) Trees into a New Resource for Feed, Fuel and Food Security in Somaliland*; PENHA briefs; PENHA: Hargeisa, Somaliland, 2016; Available online: https://penhanetwork.org (accessed on 28 April 2022).
128. Sola, P.; Njenga, M.; Koech, G.; Wanjira, E.O.; Kirimi, M.; Siko, I.; Muriuki, J. *Prosopis juliflora*—A Potential Game Changer in the Charcoal Sector in Kenya. In *Global Bioenergy Partnership (GBEP): Activity Group 4—Towards Sustainable Modern Wood Energy Development. Collection of Examples: Positive Relationships between Sustainable Wood Energy and Forest Landscape Restoration, June 2020*; World Agroforestry Centre: Nairobi, Kenya, 2020; Available online: https://www.worldagroforestry.org/publication/Prosopis-juliflora-potential-game-changer-charcoal-sector-Kenya (accessed on 28 April 2022).
129. Ilukor, J.; Birner, R.; Tilahun, M.; Getu, S. A social-economic assessment of the impact of *Prosopis juliflora* invasion and participative management approaches in the Afar Region, Ethiopia. In *Managing Prosopis juliflora for Better (Agro-) Pastoral Livelihoods in the Horn of Africa, Proceedings of the Regional Conference, Addis Ababa, Ethiopia, 1–2 May 2014*; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Bonn/Eschborn, Germany, 2014; p. 30.
130. Datona, M. Socio-economic impacts of *Prosopis juliflora* related charcoal trade in Gewane Woreda, Afar Region. In *Managing Prosopis juliflora for Better (Agro-) Pastoral Livelihoods in the Horn of Africa, Proceedings of the Regional Conference, Addis Ababa, Ethiopia, 1–2 May 2014*; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Bonn/Eschborn, Germany, 2014; pp. 129–136.
131. Lugusa, K.O.; Wasonga, O.V.; Elhadi, Y.A.; Crane, T.A. Value chain analysis of grass seeds in the drylands of Baringo County, Kenya: A producers' perspective. *Pastoralism* **2016**, *6*, 1–15. [CrossRef]
132. Shiferaw, H.; Teketay, D.; Nemomissa, S.; Assefa, F. Some biological characteristics that foster the invasion of *Prosopis juliflora* (Sw.) DC. at Middle Awash Rift Valley area, north-eastern Ethiopia. *J. Arid. Environ.* **2004**, *58*, 135–154. [CrossRef]
133. Sugur, G.V. Coppicing ability of natural stand of *Prosopis juliflora*. *Myforest* **1988**, *24*, 129–132.
134. Epanchin-Niell, R.S. Economics of invasive species policy and management. *Biol. Invasions* **2017**, *19*, 3333–3354. [CrossRef]
135. Oduori, S.M.; Rembold, F.; Abdulle, O.H.; Vargas, R. Assessment of charcoal driven deforestation rates in a fragile rangeland environment in North Eastern Somalia using very high-resolution imagery. *J. Arid. Environ.* **2011**, *75*, 1173–1181. [CrossRef]
136. Ministry of National Planning and Development, (MNDP). *National Development Plan (2012–2016)*; MNDP: Hargeisa, Somaliland, 2011; pp. 1–328.
137. Mureithi, S.M.; Verdoodt, A.; Njoka, J.; Gachene, C.K.; Van Ranst, E. Benefits derived from rehabilitating a degraded semi-arid rangeland in communal enclosures, Kenya. *Land Degrad. Dev.* **2016**, *27*, 1853–1862. [CrossRef]

138. Njoroge, E.; Sirmah, P.; Mburu, F.; Koech, E.; Mware, M.; Chepkwony, J. Preference and adoption of farmer field school (FFS) Prosopis juliflora management practices: Experiences in Baringo District, Kenya. *For. Stud. China* **2012**, *14*, 283–290. [CrossRef]
139. van Wilgen, B.W.; Richardson, D.M. Challenges and trade-offs in the management of invasive alien trees. *Biol. Invasions* **2014**, *16*, 721–734. [CrossRef]
140. van Wilgen, B.W.; Richardson, D.M. Three centuries of managing introduced conifers in South Africa: Benefits, impacts, changing perceptions and conflict resolution. *J. Environ. Manag.* **2012**, *15*, 56–68. [CrossRef]
141. Van den Berg, E.C.; Kotze, I.; Beukes, H. Detection, quantification and monitoring of Prosopis in the Northern Cape Province of South Africa using remote sensing and GIS. *S. Afr. J. Geomat.* **2013**, *2*, 68–81.
142. Kleinjan, C.A.; Hoffmann, J.H.; Heystek, F.; Ivey, P.; Kistensamy, Y. Developments and prospects for biological control of *Prosopis* (Leguminosae) in South Africa. *Afr. Entomol.* **2021**, *29*, 859–874. [CrossRef]