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THE *PROSOPIS* DILEMMA, IMPACTS ON DRYLAND BIODIVERSITY AND SOME CONTROLLING METHODS

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A study on the impact of *Prosopis juliflora*, a multipurpose leguminous species introduced to Ethiopia, was carried out at Tendaho State farm, Alidegi and Afambo, North-east Ethiopia. The study focused on the assessment of the uses and negative impacts of *Prosopis* and the evaluation of mechanical control and prescribed burning. Various PRA (Participatory Rural Appraisal) techniques were employed to collect ethno-botanical information on uses of the species. Mechanical control was evaluated by observation of previously cleared (deforested) grazing areas and farms in Alidegi and Tendaho, respectively. Data on number of stems per plant were collected along two parallel line transects to investigate the coppicing ability of the species. Prescribed burning was evaluated for mature stands (3-4 yrs) and young stands (< 1.5 yr).
The result showed that *Prosopis* is employed for firewood, charcoal, forage, fencing, windbreak and other purposes. Mechanical control (manual clearance and using bulldozers) was found to be effective followed by proper management systems. Besides, it was discovered that the number of stems from the stumped stands was significantly higher ($P < 0.05$). Prescribed burning was destructive for young stands, whereas mature stands were not killed. Generally, cutting individual plants may aggravate the invasion by *Prosopis* unless proper management such as repeated clearance is employed. Thus, proper management and control of the species is urgent using the control methods described above in cooperation with the local people. Otherwise, more areas could be invaded and tribal conflict for the remaining few grazing and farm areas free from *Prosopis* may turn into unexpected political crisis.

Key words: Desert and semidesert ecosystem, mechanical control, prescribed burning

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Introduction

Ethiopia is located between longitudes 33° & 48°E and latitudes 3° & 15°N covering an area of 1.13 million square kilometers. The country is endowed with diverse ecosystems with unique floral and faunal diversity. Recently, ten ecosystems were recognized and described among which the desert and semi-desert ecosystem is the one located to the northeastern and southeastern lowlands of the country (NBSAP 2002). The altitudinal range in this ecosystem varies from 120 m below sea level in the Danakil depression to roughly 900 m asl at the middle Awash. Peripheral to the Danakil depression there is an extended flatland, extremely hot, dry and harsh, and the slope goes gently undulating with an increase in altitude towards the central mountainous region of the country (Getachew 2002). The desert and semidesert ecosystem covers a large proportion of the landmass in eastern and southeastern parts of the country. It includes most, if not all, parts of the Afar Region. It has vast ecological, cultural, economic and social values at national and continental level. Ecologically, this ecosystem consists of diverse habitat types that support a number of endemic flora and fauna and hosts Yangudi-Rasa National Park. Culturally and socially, it provides a living space for nomads and provides spiritual and medicinal values for the people and their livestock. With regard to economic value, it supports relatively high livestock population (earns foreign currency), provides agricultural lands (mechanized agriculture), salt mining, tourism (ecotourism) at Hadar and other parts of the region.

Areas in this ecosystem are being invaded by *Prosopis juliflora* (hereafter *Prosopis*) at an alarming rate. The species is forming monospecific thickets, and roads, watering areas, farms and grazing areas are being lost. *Prosopis* originates from Central and/ or Southern America (Duke 1983, Heady and Child

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1994). The species is now pantropically introduced and is spreading, often as a weed. It is classified as a principal weed in Mexico, a common weed in the USA (area coverage-38 million hectares), and a weed in Australia, Dominical Republic, India, Iraq, South Africa and Venezuela (Harding and Bate 1991, Heady and Child 1994.). The ecology of *Prosopis,* ranges from tropical through subtropical to dry forest ecosystems (Duke 1983). The species can grow in altitudes from sea level to 1500 m asl. In Ethiopia it occurs with altitudes of 450 m to ~1000 m asl currently invading areas in the Afar and Somali Regional States (Getachew 2002). *Prosopis* is reported to tolerate annual precipitation of 150 to 1670 mm, annual temperature of 20.3-28.5^{o}C and a pH of around neutral (Duke 1983).

This study was conducted with the objective to 1) assess the impact of *Prosopis* on humans, domestic animals and dry land biodiversity in general, 2) evaluate the control options for *Prosopis* particularly mechanical control and prescribed burning, and 3) create awareness among the society in areas invaded by the species.

The study area

Topography and climate

In desert and semidesert ecosystem of the Afar Region there occurs a variety of alluvial fans, salt marshes (playas), and valley incisions (arrays) caused by the Awash River and its tributaries. The region is known for its poorly developed soil that varies depending on topography and climate (Mohr 1971). The desert and semidesert climate is characterized by scant and unpredictable precipitation, bimodal rains (i.e. February-April and July-August rainy periods) (Figure 1), and cloudless days in most parts of the year, hot summer, and temperature that varies in range between 16^{o} to 47^{o}C (NMSA 2002, Hailu et al 2004). Average monthly rainfall record in the area showed that the highest amount of rainfall is received in August, which is 27 mm and 110 mm at Assaita and Gewane towns, respectively. The driest month in the region is December with less than 2 mm rainfall. The warmest month is May about 47^{o}C and 40^{o}C at Assaita and Gewane towns, respectively, whereas the coldest month is December with 16^{o}C (Gewane).

Biodiversity

The desert and semi-desert ecosystem harbors valuable animal and plant species many of which are endemic. Some of the endemic and endangered plants (Ensermu et al 1992) include *Acacia prasinata*, *Boswellia ogadensis*, *Euphorbia doeloensis*, *E. ogadensis* and *Indigofera kelleri*. Some of the most commonly occurring wild animals in this ecosystem are Wild ass, Soemmering's Gazelle (Berihun 2001), Zebra, Warthog (Hailu et al 2004), baboons and jackal (personal observation). Getachew (2002) described about nine habitat types in this ecosystem, namely, *Acacia* woodland, grassland, open bush/shrub land, desert grass steppe, riparian vegetation, wetland, rock desert, sand/salt desert and settlement area. Desert and semidesert ecosystem is characterized by being devoid of any conspicuous vegetation (for example, the Danakil depression) to areas moderately well vegetated with shrubs (rarely trees), bush/shrub steppe, grass steppe and a variety of annual plants and succulents. Dominant plant species in this ecosystem, among others, are *Acacia nilotica, A. ehrenbergiana, A. senegal, A. etbaica, A. tortilis, A. brevispica, A. zanzibarica, A. oerfota, Balanites aegyptiaca, B. rotundifolia, Calotropis sp., Atriplex sp., Boscia angustifolia*, *Tamarix nilotica*, *Phoenix reclinata*, *Ficus sp., Ziziphus spina-christi, Cadaba rotundifolia, Capparis tomentosa, Terminalia brevipes* and *Phyllanthus* sp. Among the grasses are *Setaria, Hyparrhenia, Eragrostis, Cenchrus, Sorghum, Ochtochloa*, *Dactyloctenium* and members of the *Aristidae.*

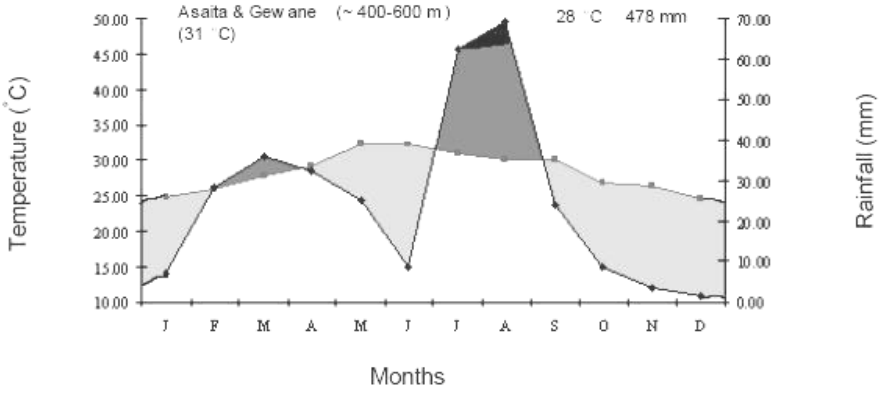

Fig. 1. Climate diagram of the study sites showing mean annual temperature and rainfall for the last 20 years (1981-2000) (source: NMSA, 2002)

Materials and methods

The plant material

P. juliflora belongs to the family *Fabaceae* (Leguminosae), subfamily *Mimosoideae* and genus *Prosopis* (Asfaw and Thulin 1989). The species could be a tree or shrub, and is armed with stipular spines 0.5-2.5 (-5) cm long. Leaves have 1-2 (-4) pair of pinnae; the number of leaflets could be 6-29 pairs with sizes 6-23 mm x 1.5-5.5 mm and glabrous surfaces. Flowers are yellowish in speciform racemes, 5-10 (-15) cm long. The pod is pale brown, linear, straight or slightly curved, 8-29 cm x 0.8-1.7 cm, compressed and with a sugary-pulpy mesocarp. *Prosopis* is salt-tolerant, growing near water holes and along wades at low altitude in southeast and northeast lowlands of Ethiopia; it is native to America (Asfaw and Thulin 1989). It is now widely cultivated in the tropics for shade, timber and forage.

The most important reasons for its fast invasion into semiarid and arid ecosystems are due to the role of livestock, deer, rabbits, and rodents in dispersal of the seeds (Heady and Child 1994). The role of rodents is often minimal as they travel short distances compared to livestock and other higher animals. Accordingly, livestock trailed at the rate of 15kms per day would transport *Prosopis* seeds in their digestive tracts more than 100 kms in a week's time.

Prosopis is propagated through its seeds, root suckers, and hardwood cuttings (Hailu et al 2004). Studies revealed that 12% to 45% of *Prosopis* seeds ingested by animals could pass unharmed through their digestive tracts. Seeds ingested by livestock typically have higher germination rates. According to Hailu et al (2004), the number of seeds recovered from one kilogram of droppings of each animal under study (goat, camel, warthog, cattle) ranged between 760 (goats) to 2833 (cattle). This shows that cattle are the major dispersers of seeds followed by warthogs, camels and goats.

The seeds can germinate under considerable moisture stress and temperature that ranges between 20-40^{o}C. Some studies (e.g. Hailu et al 2004) showed also that seeds that are treated in hot water or with acid germinate better than untreated seeds. Seeds retained within intact pods can remain viable for up to 40 years, but exposed seeds dry out or decay more rapidly (Cronk and Fuller 2001). Seeds typically germinate from soils at depths of 1-2 cm. At the seedling stage the root: shoot growth can be up to 10 times. The mature trees bear fruits after three to four years.

Data collection and analysis

The impacts of *Prosopis* were assessed from December 12, 2003 to January 2, 2004 through field observations and holding interviews with the local people in areas with potential problems. Various PRA (Participatory Rural Appraisal) techniques were employed to collect ethno-botanical information on uses of the species. The techniques include semi-structured interviews (individual and group discussion) and field observation (Martin 1995, Cotton 1996). Ten key informants of which six are uneducated and four educated were selected based on comments and recommendations from elders and authorities. Mechanical control was evaluated by observation of previously cleared (deforested) grazing areas and farms in Alidegi and Tendaho, respectively. Thus, data on number of stems per plant were collected along two parallel line transects 200 m apart to investigate the coppicing ability and its impact on the vegetation, grazing fields, farms and settlement areas as well as the role of nomads in aggravating *Prosopis* invasion. Analysis of variance (one way ANOVA) was used to reveal the difference in number of stems in stumped and non-stumped individuals using a software program known as statistical package for social scientists (SPSS 10.0 for Windows, 1999*)*. Prescribed burning was evaluated at Alidegi grazing field and Afambo farmland at two age groups of <1.5 yrs and 3-4 yrs, respectively. Selected photographs of dispersal agents, status of invasion at a farmland and a trial of prescribed burning were taken.

Results and discussion

The uses of *P. juliflora*

The use values showed that *Prosopis* is largely employed for firewood, fencing, windbreak and forage in the study area (Table 1). All informants reported no medicinal uses of the species and all educated informants and few local farmers pointed its use for enhancing soil fertility and the consumption of its edible fruits by local children. The overall evaluation indicates the wide usage of *Prosopis* for different purposes though many people still complain that its negative impacts outweigh the uses.

Table 1. Evaluation of *Prosopis* on seven use criteria (4=best; 3=very good; 2=good; 1=fair; 0=least). Note that the mean use value is the mean value given by ten key informants

Uses	Mean value	Remark
Firewood	4	Best
Charcoal	2.4	Good
Forage	3.6	Best
Medicinal	0	Least
Fencing	4	Best
Wind break	3.6	Best
Others[1]	1.6	Good
Overall mean	2.74	Very good

[1]Enhancing soil fertility, food for man, etc.

Firewood and charcoal

Prosopis is a good fuel wood candidate, with specific gravity 0.70 or higher and the wood has been termed "wooden anthracite", because of its high heat content, burning slowly and evenly and holding heat well (Duke 1983, Anonymous 1991). In Afar and Somali Regions of Ethiopia the local communities mainly the urban dwellers are using *Prosopis* for cooking and heating. In some places charcoal is produced and transported to major cities.

Fodder, shade and fence

The leaves and pods are used as forage for livestock. However, ingestion of pods over long periods of time will result in death to cattle (Duke 1983). *Prosopis* provides also good bee forage yielding superior or high quality honey (Duke 1983). It is also useful for soil protection and as windbreak. The local people also use *Prosopis* for live fence, shade (both for human and livestock) as well as ornamental purposes. In fact, it is not very uncommon to see *Prosopis* as shade tree as one travels from the Middle Awash along the way to the eastern periphery of the country.

Improvement of microclimate and soil fertility

In many parts of the study area it has formed a monospecific *Prosopis* thicket changing the scenery and the microclimate of the area. It is known to be drought and salt tolerant and invaded several degraded and bare sandy soils. Moreover, it also served for mitigation of desertification by colonizing abandoned farmlands due to salinity problems. Soils under the crowns of *Prosopis* in the desert usually have ten times more nitrogen (0.3%) than those under non-nitrogen fixers (0-0.03%) (Bhatia et al 1998). In the middle Awash reports have shown that (during the 2003 cropping season only) about 500 hectares of previously abandoned cotton farm field due to soil salinity problem were reclaimed after being colonized by *Prosopis*. Similarly, nearly 300 hectares of abandoned farmlands were also reclaimed at lower Awash (Getachew and Abiyot 2004). Thus, it is an important species for improvement of soil fertility as well as mitigation of desertification, which is a major problem of irrigated agriculture in arid and semiarid regions in Ethiopia.

Prosopis has, therefore, both economic and ecological benefit, which can be summarized as follows: it can be used for fuel wood, charcoal production, stock feed (especially during drought periods when no other green feeds are available), live fence, quality honey production, shade to human and livestock, ornamental crafts, for changing the scenery of the arid region, changing the microenvironmental condition, for soil protection and as wind break and for improving soil nitrogen and land reclamation that helps in mitigation of desertification.

Negative impacts of *P. juliflora* on humans, domestic animals and biodiversity

Due to severe environmental degradation in the area the ecosystem has lost its natural immunity to react against invasive species. Thus, *Prosopis* has become a problematic species expanding at an alarming rate in the region. It is fast growing, drought resistant, and with a remarkable coppicing power. Such unique adaptive traits of the species have got negative impact for local biodiversity and ecosystems (Getachew and Abiyot 2004, Hailu et al 2004).

Health problems

The thorn of *Prosopis* on penetrating the eye or skin of human and animals causes more inflammation than expected from the physical injury. An injury from the thorn of this species does not heal easily despite intensive medical treatments (personal communication with the pastoralists). The irritation may be due to waxes (Sharma 1981). The local inhabitants are severely affected by injury from the thorns of *Prosopis* and are complaining about its rapid colonization of the area. Using the wood in a fireplace can also cause dermatitis (Duke 1983). The available reports on cattle toxicity vary. According to reports by local Afar pastoralists, the ingestion of the pod over long periods of time will result in death of cattle. Stomach poisoning by the pod may induce a permanent impairment of the ability to digest cellulose. This might be due to the high sugar content of the pod that depresses the rumen bacterial cellulose activity and finally killing the animal.

Impact on biodiversity

Prosopis has a negative impact on pasturelands or arable fields (Getachew 2002, Hailu et al 2004), because it responds positively to overgrazing and denuded grassland ecosystems are subsequently converted to unusable bush lands. The invasion is aggravated by the aid of different dispersal agents such as cattle, camels and goats (Figure 2). The conversion of *Prosopis* invaded fields back to original condition would be very difficult and very costly (in terms of money, time and logistic resources). *Prosopis* replaced the local biodiversity in several spots in Afar region, mainly rangelands and dry riversides. In such areas the grasslands are no more used for grazing by the livestock. The species also reduced the total biodiversity of the arid and semi-arid regions by reducing their abundance, distribution, and more importantly by changing the

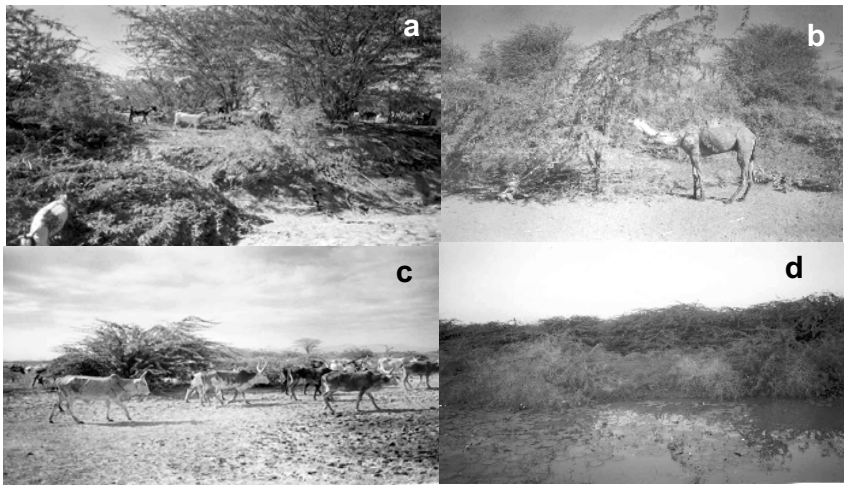

Fig. 2 a, b & c. Goats, camels and cattle feed on *Prosopis* fruits thereby dispersing the seeds; d, *Prosopis* invades watering and farm areas (Photos: Abiyot Berhanu)

ecosystem function from rangeland to *Prosopis* thicket. By doing so, it will eventually evict/push out the local Afar pastoralists (that solely depend on natural pasture for their cattle) from their home and pasture fields aggravating food and feed shortage in the region.

Public perception towards *P. juliflora*

The Afar and Somali pastoral communities generally have a negative attitude towards the species. That means that its negative impact of colonizing rangelands, farming areas, prohibiting access to waterways and causing health problems both to human and their livestock outweighs the positive impact. On the other hand, the urban communities in the regions, professionals and natural resource experts at the same time have both negative and positive attitudes towards the species. Hence, in the study areas, the dilemma still exists and no clear decision has been made or no management plan on this species is available, yet.

Prevention and control

Recently, the Institute of Biodiversity Conservation is undertaking a preliminary ecological survey and pilot experiments in the control of this invasive species. Thus, some methods such as mechanical control, prescribed burning and chemical control were adopted from countries with better experience. Chemical control, though considered effective in some countries, is not recommended from the environmental pollution point of view. For information regarding prevention of livestock, chemical control, harvesting and utilization and controlling deliberate introduction of *Prosopis* the reader is referred to Getachew and Abiyot (2004).

Mechanical control

In Tendaho State Farm, almost no regeneration was observed since the area (farm) has been managed well in the production of cotton. Thus, this method i.e. manual clearance and using bulldozers followed by proper management system was found to be effective. Despite this, it was pointed out that yearly clearance was needed to prepare the land for cotton production; otherwise *Prosopis* regrowth is frequent, because it is not totally controlled by mechanical intervention. This could be due to three events: first, *Prosopis* regrowth from the remnant root and stem stocks may take place; secondly, regeneration could be possible from the soil-stored seed banks (Hailu et al 2004). Thirdly, livestock brought to the cotton farm for grazing (after harvesting livestock is allowed to graze in the farm) might bring the seeds of *Prosopis* thereby functioning as seed dispersers. In Alidegi grazing fields, stem count revealed that the number of stems from the stumped stands was significantly higher (P = 0.034) (Table 2). This has a negative consequence on forage undergrowths as many stems block light and occupy more space.

Table 2. Comparison of stumped and non-stumped stands of *Prosopis* in Alidegi grazing fields

Status	Mean no. of stems per plant	No. of plants or stocks observed
Stumped + no additive[1]	12[a]	33
Not stumped	5	38
Stumped + Kerosene	0	30

[1]Individuals had been cut on the average 0.30 m above ground level
[a]Means are significant at 0.05 significance level (P = 0.034) (Tukey's test)

Hailu et al (2004) found out those individuals stumped 10 cm below ground did not regenerate after a couple of months, however, those individuals cut at any height above ground had high regeneration. Hence, cutting individual plants above ground may aggravate the invasion by *Prosopis* unless proper management such as repeated clearance is employed. On the other hand, addition of Kerosene on root and stem stocks was found to be effective in killing the stocks and slowing down regeneration from the sprout (personal communication). However, this method is not recommended from the environmental pollution point of view. Generally, application of mechanical control seems expensive in terms of time, energy and money.

Prescribed burning

Prescribed burning was destructive for young stands (Figure 3) whereas mature stands were not killed (Table 3). Note that *Prosopis* matures after 3-4 years. Heady and Child (1994) have also arrived at a similar conclusion. In fact, the present result might show a low effectiveness of prescribed burning unless a proper follow up is employed for a year or more.

Table 3. Effectiveness of prescribed burning of *Prosopis* at different ages

Age	Stand characteristics	Effectiveness of burning
Young (< 1.5 yrs)	Sparse	High
Mature[1] (3-4 yrs)	Thick with closed canopy	Low

[1]Individuals with fruits

The combination of different prevention and control treatments followed by prescribed fire may be effective for both the controlling and prevention of especially young *Prosopis*. Generally, prescribed burning is the most appropriate method used by far for the control and prevention of young *Prosopis* in different countries (Heady and Child 1994).

Conclusion and recommendations

Prosopis continues invading new areas and driving out pastoralists and farmers from their localities. Thus, proper management and control of *Prosopis* is urgent using the control methods suggested above in cooperation with experts and the local people. Otherwise, threats of the local biodiversity would be aggravated. Besides, tribal conflict for the remaining few grazing and farm areas free from *Prosopis* may turn into unexpected political crisis. Thus, the following points are recommended for better management and control of the species:

1. Identify those areas with potential uses as grazing, farms, and settlement and introduce prevention methods such as avoiding the usage of mature plants for fencing, otherwise by removing the ripe pods, and quarantine livestock for at least six days before moving them to new areas;
2. Organize the people (form task force) to control *Prosopis* mechanically (manually) in areas with potential uses for farming, settlement, grazing and other uses before the species becomes mature (bear fruits);
3. Remove *Prosopis* seedlings at the early stage (<1.5 yrs) and/or apply prescribed fire under controlled conditions;
4. Avoid cutting the plant randomly as it has strong coppicing ability if proper management such as repeated clearance is lacking;
5. Avoid taking the fruit to other/new areas and educate the people not to do so.

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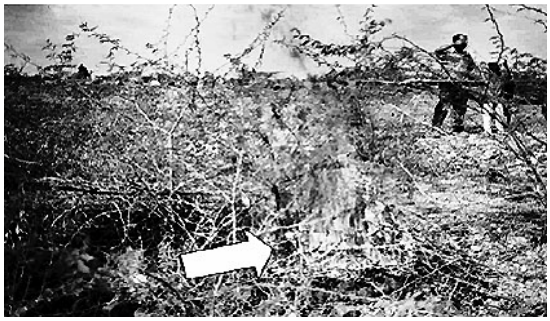

Fig. 3. Trial of prescribed burning on *P. juliflora* younger than 1.5 years. White arrow shows burning area (Photo: Abiyot Berhanu)

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