Utilization Assessment of *Prosopis juliflora* in Afar Region, Ethiopia

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Introduction

Prosopis species is one of the highly invasive plants in the world. Among the 45 recognized *Prosopis* species (Felker, 2005), *Prosopis glandulosa, P. velutina, P. juliflora and P. pallida* are reported to be generally problematic (Pasiecznik, 2001). *Prosopis* has invaded millions of hectares of land in the arid and semi-arid continents of Asia, Africa, Australia and Americas. In Africa alone, *Prosopis* is believed to have invaded over 4 million hectares, threatening crop and rangeland production, desiccating water resources and displacing native flora and fauna (Witt, 2010; Zimmerman *et al.*, 2006). However, quantitative assessments of the area covered by *Prosopis* and its rate of spread have not been undertaken in Ethiopia (Mauremootoo, 2006). In East Africa, *P. Juliflora* was introduced in the 1970s through collaborative projects involving local governments and outside agencies (Coppock *et al.*, 2005). This is very likely to be the case for Kenya and Ethiopia, but other reports suggests that introduction to the Sudan took place as early as 1917 (Broun and Massey, 1929. Although *P. Juliflora, P. Pallida and P. Chillines* are present in neighboring Sudan and Kenya (Choge *et al.*, 2007; Sallah and Yagi, 2011), only *P. juliflora* has been reported in Ethiopia. In the Afar region of Ethiopia, where *P. juliflora* is having dramatic impacts across the landscape, its spread and impacts on resources has been ranked as one of the leading threats to traditional land use, exceeded only by drought and conflict (EPP, 2006). Nationally, *P. juliflora* has been ranked as the most problematic plant invader in Ethiopia (Tessema, 2007).

Interviews of community members in the Afar Region of Ethiopia indicate that intentional planting of *P. juliflora* was facilitated by several government organizations, including the Ministry of Agriculture, Federal Relief and Rehabilitation Commission, and Zemecha Memria – a national program of Derg administration. Abas Mohamed Shami, a key informant in this study and a local Afar who organized the first *P. juliflora* planting activities in Gewane area, mentions that afforestation was part of the Derg's "Green Campaign" policy in the aftermath of Ethiopia's 1970 drought. Gewane Woreda was then under the Assebeteferi Awraja, Harerge Kiflehager. (Woreda, Awraja and Kiflehager are administrative units equivalent to counties, zones and regions, respectively). In 1979, thousands of *P. juliflora* seedlings were brought from a nursery in Hirna, Harerge, and were planted in all Assebeteferi Awraja including Amibera, Gewane, Afdem and East Awash (now known as Awash). However, the species became invasive in the early 1990s, in coincidence with the new Transitional Government in Ethiopia that is also referred to by political opposition groups as Woyane. It took only 20 years for the species to naturalize, produce a self-perpetuating community and become an independent invader. In Afar region, the tree is now known as

***Prosopis juliflora* infestation in northern Ethiopia.**

Dergi Hara, *Woyane Hara* or just *Woyane*. Experiences from other countries indicate that the tree is highly invasive and difficult to eradicate. Expensive and unsuccessful eradication efforts around the world have led the Ethiopian Government, and some NGO's, to follow a strategy of controlling *P. juliflora* through utilization.

Objectives

The objectives of our study were to:

1) Investigate the diverse uses of *P. juliflora* globally to determine if and how the species may augment the livelihoods of Afar people in Ethiopia;

2) Assess existing *P. juliflora* control and utilization strategies and evaluate their profitability and application for Ethiopians;

3) Develop preliminary maps of the potential habitat and distribution of *P. juliflora* for the Afar Region and Ethiopia.

Methods

Study Site

The study was conducted in North Eastern part of Ethiopia, approximately located between 8^0 51' and 14^0 34' latitudes and, 39^0 47' and 42^0 24' longitudes. Afar can refer to the place as well as the people living in the area. The population is largely rural and pastoralist. Afar, which is further divided into five smaller administrative zones is one of the nine administrative regions in Ethiopia. It has an arid and semi-arid climate with most of its Northern part being salty and or below sea level. The study however focuses on the Southern and central part of Afar where *P. juliflora* invasion is widespread. Elevation ranges from -144 m B.S.L to 2,870 m A.S.L. Rainfall in the central Afar area ranges from 330 mm to 820 mm. Although extreme temperatures were recorded in the Northern part of Afar, in the central area 35 years of metrological records show that the average lowest temperature is 9 ^{0} C and average highest temperature is 40^0 C (Kebede, 2009).

Literature Review

A search and review of scholarly articles were conducted using resources from the Colorado State University library, including the Web of Science® online academic citation index (http://apps.webofknowledge.com/) and Google Scholar© Search engine. Additional studies and reports compiled by government organizations and non-government organizations (NGO) on *P. juliflora* were collected from various government and non-government sources in Ethiopia, and properly investigated. In addition, student theses and dissertations completed within and outside of Ethiopia were reviewed.

Economic Analyses

Local knowledge was used to identify zones and woredas that have been affected by *P. juliflora* invasion in Afar Region. Kebele's (the lowest administrative areas) and households were then randomly chosen from the selected zones and woredas. Field visits were made to selected kebeles and households where group discussions were conducted with pastoralists, agro pastoralists, and farmers. Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis

(Ommani, 2011) was used to evaluate the effectiveness of existing *P. juliflora* utilization strategies. Rapid market assessments were conducted for important *P. juliflora* products and compared with cotton, a potential *P. juliflora* replacement crop in Afar valleys. Cash flow information was collected and profitability of converting *P. juliflora* invaded lands into irrigated cotton farms were assessed using Net Present Value (NPV; Connor, 2006) and Internal Rate of Return (IRR; Johnstone, 2008) models. High discount rate, 21 % was used on purpose to adjust for low or non-existent land rent, tax rates, and other risk factors. IRR, the discount rate that makes NPV 0, was calculated using the trial and error method. For a given time of cash flow - t, discount rate of –i, and a net cash flow (inflows less outflows) of-R, the Net Present Value is given by:

$$\mathrm{NPV} = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

Positive NPV results and higher IRR values indicate profitability.

Spatial Analyses

We conducted two spatial analyses to model the distribution of *P. juliflora* at the country-level and for the Afar Region. Our first species distribution model was a simple environmental envelope model covering the extent of Ethiopia. From our literature search, we found that *P. juliflora* has defined climate parameters. The species is known to occur in areas where precipitation ranges between 100 mm and 1000 mm; elevation from 0 to 1500 m, and mean annual temperature is greater than 20 ^{0}C (Pasiecznik, 2001). Climate data for Ethiopia was obtained from WorldClim (http://www.worldclim.org/bioclim) representing precipitation and temperatures in digital raster formats, and elevation determined from a Digital Elevation Model (DEM). The raster calculator function was then used in ArcGIS (Version: 10.0; ESRI, 2011) to identify the suitable ranges of the species.

At the regional level, a more detailed species distribution modeling approach was followed using six environmental predictors and the Maxent (Version: 3.3.3K; Philips *et al*, 2006) species habitat modeling software. The predictor variables included the distance from water, distance from roads and soil layers acquired from the Woody Biomass Project (Sutcliffe, 2006), and elevation, slope and aspect derived from our DEM at 30 m resolution. Predictors were assessed for multicoliniarity using VisTrails, SAHM package (Callahan *et al*., 2006). A total of 168 presence points for *P. juliflora*, collected from the field in spring 2012, were used to train the Maxent model. A total of 5,000 iterations were run with 25 random presence points withheld to test the model.

Results

Prosopis as Animal Feed

Prosopis species are widely known for their use as animal feed. Fruits of *Prosopis* are sweet, nutritious, have low concentrations of tannins and other unpalatable chemicals (Pasiecznik, 2001). However, the leaves are unpalatable and the seeds, which are high in protein, are not easily digestible by animals, requiring some form of grinding and processing by humans. In India, chemical composition and nutritive value of *P. juliflora* has been well reviewed and compiled. As a dry fodder, pods of *P. juliflora* contain, 15% crude sugar, 12% crude protein, a moderate level of digestible crude protein with high level of energy; seeds contain 31-37% protein (Sawal *et al*., 2004).

In several parts of Afar, Ethiopia, *P. Juliflora* has become a major source of dry season feed for goats, camels and donkeys. Cattle and sheep also feed on the pod but a local disease called 'Armeku', that affects the nervous system of these animals has been reported by Afar pastoralists. The symptoms described by pastoralists in this study are consistent with a neurological disease described by scientists in Brazil. According to this Brazilian study, the cranial nerve function of cattle and goats that fed a ration containing 50 % and 75% of dry ground pods, were impaired and denervation atrophy has occurred in masseter and masticatory muscles (Tabosa *et al*., 2006). With the right proportion, however, *P. juliflora* pods can be effectively used in animal feed industry. Mahgoub *et al*. (2003), found that 20% proportion or 200 g/kg, *P. juliflora* pods can improve feed intake, feed conversion, and body weight gain of Omani goats without compromising product quality. In Ethiopia, 10 and 20% inclusion of ground *P. juliflora* pods was found to reduce feed production costs without compromising biological performance. At 30%, however, the positive results of *P. juliflora* diminished with the growth and feed intake of poultry (Girma *et al*., 2011).

The average amount of pod produced by one tree in a single year ranges from 20 Kg to 50 Kg (Pasiecznik, 2001). Farm Africa, an NGO working in Afar region of Ethiopia has introduced *P. juliflora* pod grinding machines, and has formed cooperatives that carry out pod harvesting, collection, grinding and selling activities. In addition to generating income to cooperative members, this strategy will reduce propagule pressure and play a positive role in carbon sequestration. However, to become a good profitable business activity, the strategy needs reliable market and good rainfall. With good rainfall and successful pollination, *P. juliflora* seeds can flower, fruit and produce pods twice in a single year. The primary constraints to a business are the seasonal variability of the region and lack of dependable market/markets for large scale production. Currently, cooperatives prepare *P. juliflora* flour after receiving orders from buyers. The opportunities include presence of *P. juliflora* stands near water sources that can produce pods independent of rainfall availability, and presence of small local markets. Several feed processing plants exist in the country and the people who run these plants seem to be unaware of the value of *P. juliflora* as a feed constitute. Feed processors as well as dairy and fattening farms located in Afar region and its vicinities should be targeted and should be communicated about the high nutritive value of *P. juliflora* pods and its role in reducing animal feed cost.

Use of Prosopis for Energy Production

Energy from *Prosopis* can be obtained through several ways that include, direct burning, carbonization, gasification, pulverization, and fermentation (Pasiecznik, 2001; Silva *et al*., 2011). *Prosopis* trees are good sources of fuel wood around the world; in Ethiopia, the trees are made into charcoal which are then transported and sold in urban areas. Over 90% of energy consumption in Ethiopia comes from biomass fuel (Mekonnen, 2009). Currently, most of the fuel wood biomass in Afar region comes from *Acacia* and *Prosopis* trees.

According to a FAO estimate, in 2010, Ethiopia produced 3.7 million tones of charcoal and exported 84 tons to other countries (FAOSTAT, 2011). It should be noted, however, that unsustainable harvesting can lead to deforestation. In Ethiopia, cutting indigenous trees for fuel wood purposes has resulted in loss of natural forests and land degradation (Haile *et al*., 2010; Mekonnen, 2009). In the Afar Region, indigenous trees are still harvested for energy purposes, but the availability of *P. juliflora* has relatively reduced the harvesting pressure on local trees.

Women removing uprooted *P. juliflora* stumps from invaded lands in the Afar Region, Ethiopia.

The high demand and consumption of charcoal in the country, and suitability of *P. juliflora* for charcoal production have resulted in some form of control through utilization. Charcoal in the Afar region is produced traditionally with very minimal cost. Earth mounds are built at harvesting sites; hence, there is no or little transportation cost of raw woody material. This traditional method doesn't require large investments and the labor associated with charcoal production is cheaply available in the area. Moreover, production size is not a limit. There is well established market channel that begins at the production site and ends at the consumers door step (Kwaschik, 2008; EPP, 2006). However, policies regarding charcoal production vary and are frequently modified. At the time of this report, several loopholes exist in the various regional laws and regulations. As a result, the legality of charcoal production is poorly defined and difficult to regulate. For example, indigenous trees such as *Acacia nilotica*, *Tamarix aphila*, and *Combretum aculeatum* are harvested for charcoal production legally from leased woodlands and illegally from communal lands.

Controlling *P. juliflora* invasion through charcoal production requires the removal of its stumps. This is often not case, however, because stump removal incurs additional time and labor costs. Additionally, the removal of stumps decreases the resource base, thereby affecting the sustainability of this scheme. It would seem that for charcoal production to be an effective control mechanism, it needs to be legalized and should be implemented according to the regions *P. juliflora* control guidelines. Experience from bamboo management, increased valuation, and marketing by INBAR (International Network for Bamboo and Rattan), and other private companies in Addis Ababa should be examined as a model in *P. juliflora* products processing and marketing.

Prosopis Wood Products

Studies indicate that good quality lumber can be produced form *Prosopis* wood. *Prosopis* lumber compares favorably in color, hardness and shrinkage values to the world's finest timbers (Felker, 1999; Gomes, 2007). All data for physical and mechanical properties of *P. juliflora* wood fall well within acceptable limits for making wood products (Pasiecznik, 2001). The wood is resistant to termites, and white and brown rot fungi; is dimensionally stable and its mechanical properties compared well with *Pinus patula*, a wood widely used in Kenya for construction purposes (Sirmah *et al*., 2008). However, trees are often crooked, thorny and have short harvestable trunk. As a result, short length wood products are produced form *P. juliflora* trees. The wood products can be used for fine furniture and flooring (Felker, 1999), railway slippers (Sirmah *et al*., 2008), and tool handles (Shukla *et al*., 1990). A single layer particleboard that was produced from *P. juliflora* with 11% resin content and a five-minute press cycle was found to be adequate for general uses (Ashori and Nourbakhsh, 2008). Mixing *P. glandulosa* chips with other tees in USA has also resulted in acceptable chip wood product (Hiziroglu, 2010).

In the Afar Region, *P. juliflora* trees are harvested for a less quality product, (e.g., charcoal) before they reach maturity. The current study found the presence of only a few mature stands that could be used for lumber production. Currently, *P. juliflora,* or even the larger sized *Acacia nilotica* trees, are not harvested for timber or lumber products. Nevertheless, studies made in Ethiopia and other countries suggest that management of *P. juliflora* for commercial timber could a profitable and successful business venture (Zewdie and Worku, 2009; Felker and Guevara, 2003).

The drawback of this business plan comes from keeping the trees for long periods of time. Trees kept for several years will become seed sources, increase the propagule pressure, and will facilitate new invasions. The plan may also violate local policies and guidelines since the control guidelines for *P. juliflora* in the Afar Region recommends harvesting before seed setting (Anonymous, 2002). Combining pod harvesting with timber production may help resolve these issues.

Use of Prosopis for Other Products

Prosopis species are good sources of nectar and honey production. The species are also known for its food and gum products that can be produced from its pods and barks. Unfortunately, these qualities were not considered when *P. juliflora* was first introduced to Ethiopia. Compared to other *Prosopis* species, *P. juliflora* pods are bitter and inedible (Felker, 2005). In Kenya bread made with 20% *P. juliflora* pods have a good taste and nutritional value; but the presence of aflatoxins and ochratoxin A has warrant additional investigations before any recommendations are given (Choge *et al*., 2007). In Brazil, highly nutritious honey-like syrups

At the Adal Bamboo Flooring and Charcoal Factory, in Addis Ababa, several products are produced from bamboo stems. Round and split bamboos are used for house construction while laminated bamboo boards, veneers and panels are used to make furniture, flooring, roofing, curtains, as well as door and window frames. The remaining short length splits are used to produce table mats, incense sticks, tooth picks, match sticks and tip holders. Bamboo sawdust and leftovers are then carbonized into charcoal through efficient retort kilns that have high carbonization efficiency and emit little amount of pollutants. The charcoal is converted into briquettes, properly packed and sold at national and international markets.

were produced form *P. juliflora* pods that can be combined with other ingredients to produce cakes, cookies and other bakery products (Guilherme *et al*., 2007).

Extractives of *P. juliflora* have a potential to be used as natural antioxidants in the food, cosmetic or pharmaceutical industries (Sirmah *et al*., 2011). A study made in India indicated that activated carbon, which has applications in environmental cleaning, can be produced form *P. juliflora* trees (Kailappan *et al*., 2000). These and other food or industrial uses of the tree have yet to be explored in Ethiopia.

Conversion of P. Juliflora Invaded Lands into Commercial Farms

The last proposed strategy to control *P. juliflora* investigated in the current study is the conversion of invaded lands to irrigated farms with a one-time production of charcoal as a by-product. Conversion ensures removal of *P. juliflora* and reduces the likelihood of re-infestation. In Awash, Sheleko and Melkasedi areas of Afar, where irrigated farming is commonly practiced, agro-pastoralists have suggested that *P. juliflora* may be controlled soon. Onions, tomatoes and other vegetables are being grown in reclaimed lands. Perhaps the best option, however, is the conversion of invaded lands into cotton farms. Cotton can be grown in all three Awash watersheds (Upper Awash, Middle Awash and Lower Awash), and there is a long tradition of cotton farming already present in the region. Technical support is available from the nearby Worer Institute of Agricultural Research, and knowledge can be transferred from investors working in the area to small scale farmers or cooperatives. Cotton farming can be started with little initial investments. Machineries and equipment are readily available for rentals, and cotton has a relatively longer shelf life and is not considered a perishable crop. Moreover, settled farming in Afar region is encouraged by federal and regional policies (MoFED, 2010).

The demand for cotton is high in both domestic and international markets. India, Pakistan and Thailand are already major cotton exports for Ethiopia. The economic benefits of cotton farming are numerous and would benefit multiple levels of Ethiopian society, including small holding farms, private commercial farms, state farms, local assemblers, ginners, handlooms and hand crafts, spinning and yarning plants, textile mills, garment and apparel factories, oil mills, dairy and fattening farms, wholesalers, retailers, and consumers. There are risks, however, and drought, rising fuel costs, Ethiopia's high rate of inflation, (CIA fact book, 2011), loss of land productivity, and access to credit (Bosena *et al*., 2011) could be problematic.

Field experiments conducted near Alage and Ziway, with a seed obtained from Metehara (near Afrar region), suggested that *P. juliflora* has an average annual yield of 13 m^3/ha on fresh weight bases (Abebe, 1994). At 10% moisture content and 810 kg/m^3 average density given for the species (Pasiecznik, 2001), the above-ground wood biomass that can be obtained in a year is 10,530 kg or10.5 tons/ha. Therefore, from a five year old *P. juliflora* stand, one can get 52,650 kg or 52 tons of wood biomass that can be used for charcoal making. At 1:4 average biomass to charcoal conversion rate (Pasiecznik, 2001; Kwaschik, 2008) this will result in 438 bags of charcoal per ha, each weighing 30 kg. A bag of charcoal is sold for 65 Birr in Afar, and for 75 Birr at Addis Ababa market. After deducting 8,500 Birr for wood harvesting, stump excavation, packaging and other labor costs, at Afar, a net profit of 20,000 Birr/ha can be obtained from charcoal production. With this amount of money, one can buy a good water pump for a cooperative or an individual farmer who will be involved in this conversion plan.

Table 1. Costs associated with *P. juliflora* removal and conversion to irrigated cotton farm. Data collected using rapid market assessment tools in March 2012.

Activity	Cost/ha in Birr		Sale in Birr		Profit before Tax	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Prosopis harvesting, stump removal and charcoal making and selling	-	3,000	20,000	-		
Water Pump including Maintenance	20,000	2,000	-	-		
Plowing and seed bed preparation (Rental)	2,500	2,500				
Water Canal construction, maintenance, and ridging	2,400	2,400				
Improved seed	400	400				
Labor cost for watering and guarding	4,100	4,100				
Weeding and Thinning	1,100	1,600				
Chemical costs	1,800	2,000				
Gas, oil and labor cost for chemical application	700	700				
Motorized Chemical Sprayer including maintenance	2000	400				
Harvesting costs	2,500	2,500				
Packaging for 32 Quintal	2,500	2,500				
Transportation cost, 60 Birr per Quintal	1,800	1,800				
Depreciation cost for Sprayer and Water pump (with good maintenance and straight line method)	1,500	1,500				
32 Quintal of Raw Cotton at 1,200 Birr for year one and 1,250 Birr for year 2, at Awash Market	-	-	38,400	40,000		
Total	43,300	27,500	58,400	40,000	15,100	12,500

Using cash flow data showed in Table 1 and 0.21 discounting rate, NPV calculated for the first year has a positive value. (0.826 * 58,400) – 43,300 = 4,938. Similarly, NPV calculated for the second year is positive. (0.697 * 40,000) – 27, 500 = 380. Total NPV = 5, 318. The Internal Rate of Return, IRR, calculated using the cash flow statement shown in Table 1, approximately equals 27 %. $(58,400) / (1 + r)^{1} + (40,000) / (1+ r)^{2} - 43,300 - 27,500 \approx 27\ \%$

Both NPV and IRR models indicate that converting *P. juliflora* lands into irrigated cotton farms would likely be profitable. Studies that compare productivity of traditionally managed pasture lands with irrigated farms have not been conducted for the Awash Valley; however, privately and cooperatively owned farms generally are more profitable when compared to state owned farms (Behnke and Kerven, 2011). When trying to control the negative impacts associated with invasive species, the benefits from land conversion and/or other strategies to increase value from the land outweighs the costs of doing nothing. The advantages of large-scale commercial farming in Awash may be debatable, but the results of this study suggests that converting *P. juliflora* invaded lands into small-scale cooperative owned cotton farms is a cost effective control option while providing much needed economic support to the community.

Potential Habitat and Distribution of P. juliflora

Correlation tests conducted using VisTrails SAHM package indicated that predictor variables were not correlated. The results from the environmental envelope model indicate that about half the area of Ethiopia may be at risk of *P. juliflora* invasion. Regions that have the highest risk of invasion include Afar, Somali and Dire Dawa; however, suitable habitats are also present in Tigray, Oromia, Amhara, Southern Nations and Gambela regions.

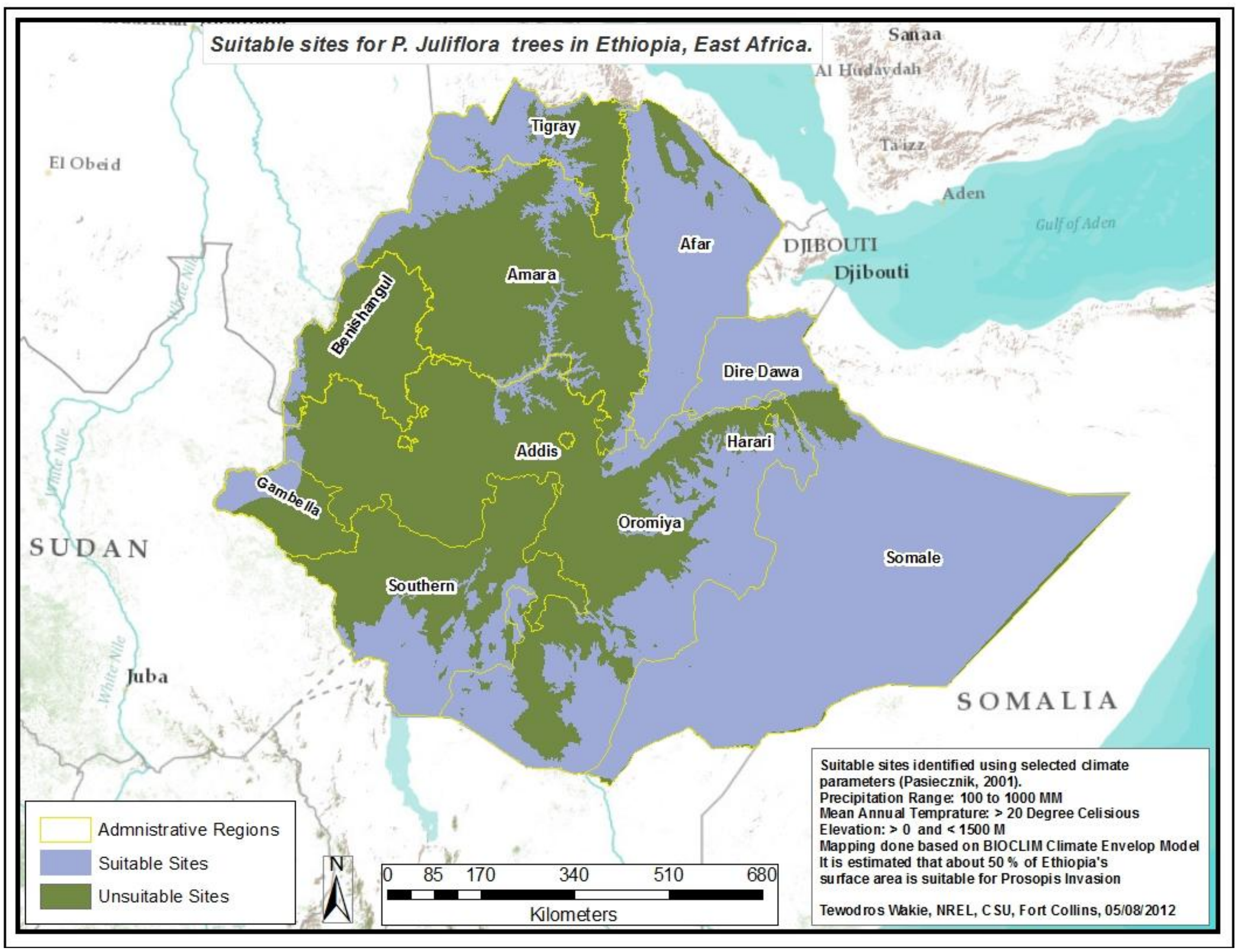

Figure 1. Map showing suitable habitat (blue) and potential distribution for *P.juliflora* in Ethiopia using environmental envelope model.

Among the six variables used to predict potential distribution in Maxent model, distance to water, distance to road, soil types, and slope were found to have the greatest predictive contributions (Table 2). Distance to road contributed the most with percent contribution of 58.8 and permutation importance of 53.4, AUC = 0.976. Maxent results were further processed in ArcGIS using the ten percentile logistic threshold value, 0.2395 and categorized as suitable and non-suitable habitats.

Table 2. Permutation importance and percent contribution of predictor variables as reported in the Maxent model results.

Variable	**Permutation Importance**	**Percent Contribution**
Distance to Water	58.8	53.4
Distance to Road	27.4	37.9
Soil Type	6.2	1.0
Slope	4.4	5.6
Aspect	2.8	0.4
Elevation	0.5	1.5

The Maxent model results indicate that the suitable habitat of *P. juliflora* in the Afar region is about 400,000 ha. The area predicted by the Maxent model is smaller than the results predicted by Climate Envelope Model; however, the Maxent model predictions are similar to map that was produced by Afar Ministry of Finance and Economic Development office using conventional surveying methods (Personal communication with Mensur B., MoFED Afar Regional Bureau staff). Though not 100 % accurate, our predictions are more realistic and superior to other mechanistic approaches that give coarse estimates. For instance delineating a 0.5 to 3 km buffer zone around Kenya’s Turkwel River resulted in an estimated *Prosopis* threatened area of 3 to 27.7 million ha (Muturi *et al*., 2009). Nevertheless we believe that incorporating additional *P. juliflora* present points will improve our results.

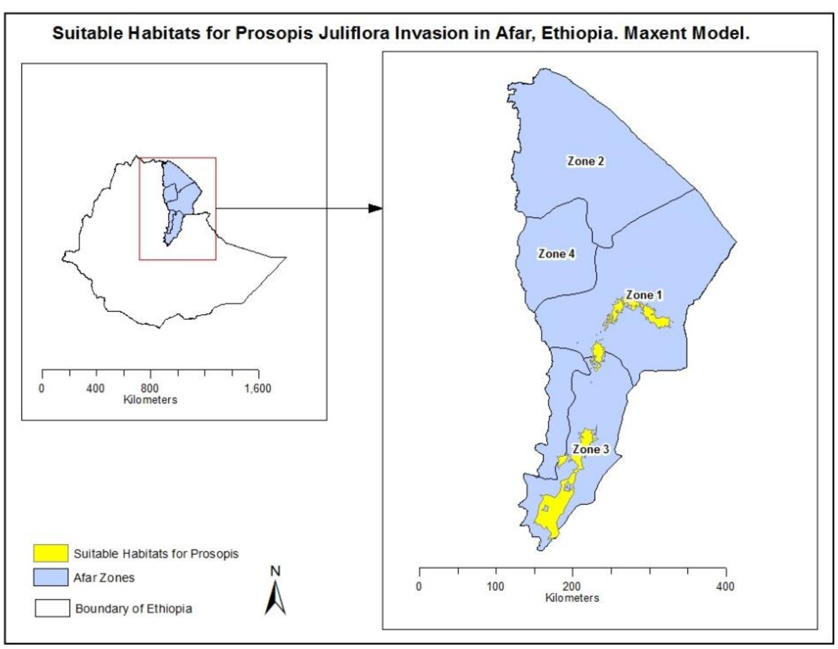

Figure 2. Maxent model results showing suitable habitats (yellow) and potential distribution for *P. juliflora* in Afar Region, Ethiopia.

Conclusion and Recommendation

All utilization plans discussed in this paper have potential in controlling the invasion of *P. juliflora* in Ethiopia. However, conversion of invaded lands into irrigated farm lands with a charcoal by-product is found to be the best strategy both in terms of controlling the invasion, as well as augmenting the livelihoods of the people. In addition to ensuring removal of *P. juliflora*, this conversion scheme would be profitable with NPV of 3000 and IRR of 21 %. The potential for irrigated cotton farming in Afar region is substantial with an extensive value chain. Today, small-scale farmers and cooperatives already sell raw cotton to bulk purchasers and exporters. With the minimal support, however, there could be new opportunities for small-scale farmers and cooperatives to supply farm tools and equipment, provide transportation of goods, grow organic cotton, or elevate their business to ginning and exporting.

The use of *P. Juliflora* flour as animal feed constitute has been demonstrated in several countries, including Ethiopia. Up to 20% inclusion of *P. juliflora* flour in animal feed products is safe and can reduce cost of feed production. Using *P. juliflora* pods has dual benefits because it reduces the availability of seeds for dispersal while augmenting the livelihood of people engaged in the plan. Nevertheless, cooperatives should take a proactive step in contacting people involved in animal feed processing industry and product marketing.

Short-length wood products can be produced from *P. juliflora* trees. However, tending and nurturing *P. juliflora* implies protection of invasive trees which otherwise needs to be eradicated. The stands can also become potential seed sources for further invasion. Hence, it is recommended that timber production be conducted in combination with pod harvesting or fencing. Farmlands that are abandoned for long periods of time may be ideal for this approach. Such areas contain mature *P. juliflora* and *A. Nilotica* trees that are suitable for lumber products. More efficient harvesting and milling techniques need to be introduced at such sites. Whenever possible, wood should be the priority product obtained from *P. juliflora* trees, as producing wood is more profitable than producing charcoal. More efficient carbonization techniques, such as metal Kilns, retort kilns, improved earth mound kilns, and brick kilns should be considered. Low cost briquette making technologies, such as crusher and hand-pressed, should be introduced; the products should be properly packed, and promoted for both domestic and international markets. It is recommended that the Adel's experience on Bamboo wood processing and marketing be tested.

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