

## **Ethiopia-National Plan for Prosopis-3 February 2002 FINAL DRAFT**

**Title:** A *Prosopis* network to coordinate integrated National *Prosopis* plans that include; resolution of environmental problems, genetic improvement, control of weedy stands, marketing and development of sustainable industries.

**I Short term goal.** Increase food security, economic welfare and environmental stability with whatever means possible through *Prosopis* based ecosystems.

**II Long term goal** - Create stable jobs in *Prosopis* food and or lumber industries that take people from hand to mouth poverty existence that provide regular paychecks with benefit packages.

Caterina Batello, Agricultural Officer, Plant Production and Protection Division of FAO provided initial funding in April 2001 to contract with Peter Felker to initiate comprehensive national development plans for *Prosopis*. The plans are intended to meet urgent short-term needs of food and firewood and long term goals of income and environmental stability. The plans will also include applied research, comprehensive economic assessment, market analyses and attraction of private sector investment. It is envisioned that in mid to late 2002 a workshop will be held in which individual countries will present their respective national plans to potential donor agencies. In September 2001, the countries involved in the network were India, Pakistan, Sudan, Kenya, Ethiopia, Niger, Mexico, Peru, Brazil, and Argentina

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## **Introduction to Ethiopian national plan for *Prosopis***

FAO has initiated a world wide network on *Prosopis* to more fully and rationally use this resource while at the same time counteracting the spread of undesirable variants of this genus. Various countries are preparing strategic plans to more effectively deal with both long and short-term problems and potentials. To assist in comparing the plans of various countries a broad outline has been devised that covers nearly all of the broad issues. Not all of the issues will pertain to all of the countries and the priorities for the countries will undoubtedly be very different.

The role of *Prosopis* in Ethiopia must be placed in context of its large population for an arid country (60 million people), the fact that it has one of the worlds lowest per capita incomes (\$100) and the fact that many of the poorest people live in northern semi-arid regions where the *Prosopis* exists. Given the fact that 75% of Ethiopia's energy is derived from fuelwood, and that this crisis is more critical in the northern arid lands, *Prosopis* has an important role to play in the provision of fuelwood. Additionally, as *Prosopis* lumber which is one of the worlds most dimensionally stable has been extensively used to produce high quality furniture, flooring and molding in Argentina, Mexico and the USA, this high value application needs to be fully developed. Ethiopia has virtually no lumber exports, as the plantations of Cupresses, Eucalyptus and Pinus are not suitable for high quality furniture. As the furniture manufacturing industry is labor intensive and as high quality furniture components and/or finished furniture can be made from small diameter *Prosopis* logs using new techniques, *Prosopis* could play a significant role in the generation of employment and foreign exchange in the development of new labor intensive furniture industries. The great deal of "waste" produced as a by-product of furniture manufacture from small diameter logs would make an important contribution to the fuelwood energy problem. At the same time this utilization would contribute to the control of weedy *Prosopis* stands. *Prosopis* stands have low production of 9% protein, 35 % sucrose pods if significant amounts of rain occur during flowering and the 90 days prior to normal pod maturation. However drought conditions such as lack of spring rains during flowering and continued stress to normal fruit maturation are a great stimulus to pod production in *Prosopis*. Pods produced under these drought conditions would provide a significant human and animal food source to complement lowered production of annual cereal foodstuffs. New erect *Prosopis* clones with small thorns and high production of highly palatable human pods have been identified in Peruvian field trials that have had exceptional performance in field trials in Haiti, Cape Verde and India and need to be field tested in Ethiopia. These clones can be reproduced with high efficiency by rooted cuttings and grafting (also onto coppice sprouts from harvested stumps) and clonal seed orchards could be used to produce improved seed. Simple techniques are available to produce flour from the pods that can be used for direct consumption in the field. With an additional grinding to reduce particle size, a flour can be produced that is suitable for upscale restaurants, bakeries and international health food/organic markets for flavor /aroma enhancement in baked goods.

The Institute for Agricultural Research (IAR) has taken the lead in developing *Prosopis* control through utilization initiatives. Various seminars have been conducted and broad support for both utilization and control of *Prosopis* has been expressed. The

following discussion provides suggestions for short term and long term sustainable development strategies to minimize the weedy problems as well as provide food and sustainable industries with new employment opportunities.

**I Control of weedy stands through utilization, replacement with better varieties, use of competition from large trees as well as herbicides, mechanical control etc.**

Researchers at the IAR have expressed a strong concern that the Ethiopian *Prosopis* National Plan contain a very strong component on the control of the weedy stands and insofar as possible, the control be via utilization. The control through utilization approach has the significant advantage that the cost of control is borne by the utilization thus leading to an economically sustainable control mechanism that can be independent of government subsidies. It is important to point out that while the *Prosopis* in Ethiopia has some benefits, it is a result of random introduction of genetically unselected material and that other useful *Prosopis* species i.e. *P. alba* in Argentina and *P. pallida* in Peru are not weedy.

Use of recently selected Peruvian *Prosopis* clones (Alban et al., 2001) from erect, trees with abundant production of sweet pods as a sort of biological control against the weedy ones should be pursued in a research environment. In the worst case scenario should the new germplasm be as weedy as the current plant materials, at least the new weed will have erect growth, low spines and pods that are highly palatable to humans.

**Management of the *Prosopis* weedy issue**

The current and/or potential weediness of *Prosopis* is very significant and important issue and is by far the most complicated of all the *Prosopis* issues. While individual trees have been killed with 100% success and while particular tracts have had 100% of the trees killed, in no geographic region in the world has *Prosopis* been permanently eliminated. Achievement of a *Prosopis* distribution that is acceptable and economically sustainable is a challenge

If there is something that can be learned in Texas from 60 years of bulldozing with rootplows, aerial spraying and root basal treatments that have cost hundreds of millions of dollars, it is that just eliminating the present trees without an aggressive post control program will fail. If a *Prosopis* is going to be cut from the edge of a farmer's field, the stump must be poisoned or dug out - or the resprouts grafted with desirable trees with erect stems, and highly desirable pods. If something is not placed in the same location to provide permanent competition it is just a matter of time until more of the wild undesirable *Prosopis* will take the place of the one that has been removed.

The complicated problem of controlling spread of introduced *Prosopis juliflora* in areas such as the Sudan, Ethiopia, Kenya, and India has never been solved at a regional level and there are no proven solutions. Fortunately we now know a fair amount about large trees providing competition to keep the little ones from becoming established and the fertility reasons for *Prosopis* spreading in the first place. It is essential to use these concepts in an integrated biological control program. It would seem that an integrated management of at least the following 4 techniques offers the best hope for success.

**A** The first is understanding and managing the stand density/size class relationships by thinning and pruning to allow intra-specific competition to prevent colonization of new trees. Figure 1 below taken from 28 plots in Texas with log of the basal diameter on the y axis and log of the stem stand density on the x axis shows a straight line relationship in going from 18,000 trees per ha with a mean stem basal diameter of 1.88 cm to a density of 100 trees per ha with a stem basal diameter of 38 cm. This implies that self-thinning occurs in dense stands and that a closed canopy of large trees may prevent the establishment of dense stands of immature trees beneath their canopies. Thinning techniques would include killing individual trees in dense stands (with herbicides, diesel oil or uprooting) while still maintaining close to full canopy cover to prevent encroachment of new seedlings. When the remaining trees grew larger and fully reoccupied the canopy, an additional thinning would be conducted.

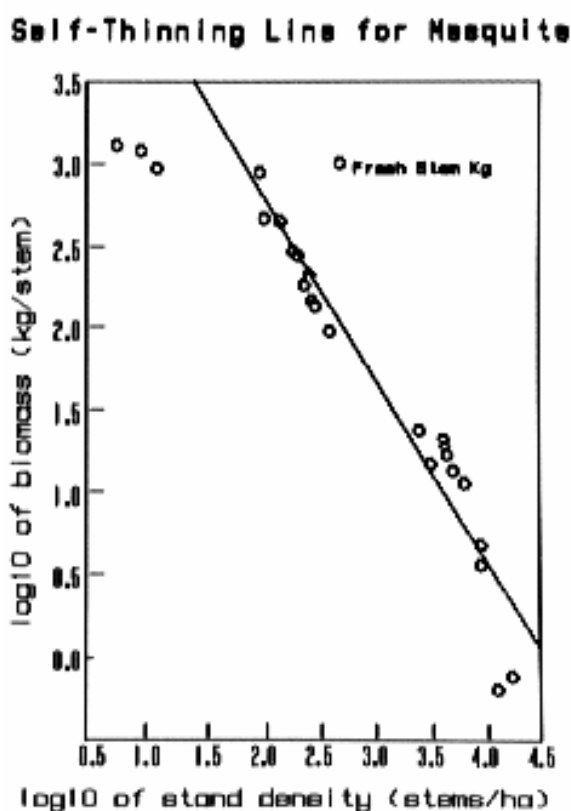


Figure 1. Self-thinning line for mesquite that describes relationship between tree size and stand density (Felker et al., 1990)

**B.** The second management technique involves replacement of the weedy species with non-weedy species in a form of biological control. This could be done either entirely in an area or possibly as a barrier around the existing weedy distribution to prevent further spread. Non weedy species would include *Prosopis alba* which is not very well adapted to the low latitude tropics and the Peruvian *Prosopis pallida* which in the low latitudes has been proven to be erect, fast growing with high production of pods that are highly palatable to humans. The park like plantations of erect Peruvian *Prosopis* of Mr. da Silva in Brazil (Figure 2) and in Peru point to the non-weedy nature of these trees. With the recent advances in grafting both small (2 mm 30 day

old seedlings) and resprouts of mature trees in the field, it will now be possible to convert the undesirable weedy stands into highly desirable non-weedy stands, by harvest of the trees, and grafting the resprouts with superior non-weedy scions. This does involve placing a small plastic shade over the grafted resprout (Figure 3).

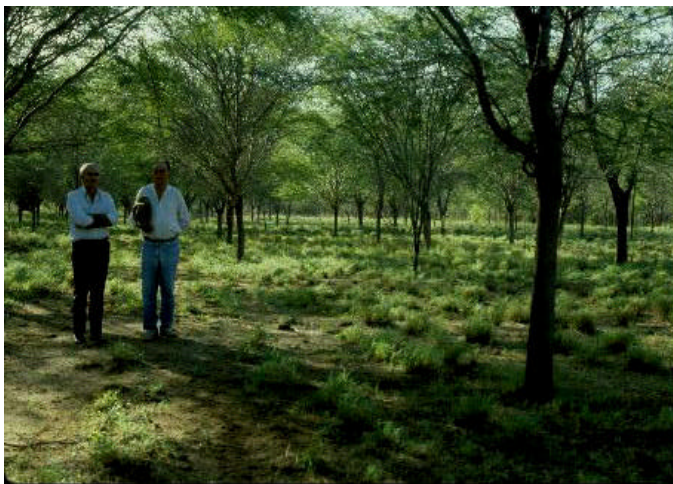


Figure 2. Mr. da Silva's *P. pallida* plantation in Brazil illustrating the absence of invading seedlings.



Figure 3. Grafted *P. alba* onto weedy *P. ruscifolia* illustrating plastic shade used to protect the graft from sunlight in the field.

**C** The third management technique involves development of markets for the wood of the stands to increase pressure on the harvest. In addition to well known products such as charcoal, firewood and posts there are at least 4 additional types of much higher value products that can be obtained from small diameter stems and trunks that are; parquet flooring, edge glued panels, finger joint boards and furniture components. Each of these products would have a price of \$2 per board ft or \$850 per cubic meter or \$1000 per ton. As these operations are labor intensive, they are not appropriate for developed countries but their production in developing countries with low labor costs and a severe weed problem could develop into a significant industry. The production of these products is possible given the excellent stability of *Prosopis* in relation to other fine hardwoods. As only the heartwood is usable (due to unstable nature and susceptibility of the yellow sapwood to powder post beetles) a trunk generally has to be 18 cm in diameter to yield a heartwood diameter of 8 cm. There are a variety of portable sawmills costing about \$25,000 capable of very efficiently converting these small diameter logs into squares (cants in forestry terms) at a rate of 0.4 cubic meters (\$160) per hour. These squares could be processed into any of the 4 high value added products described below.

(i) Parquet flooring. Typically parquet flooring has a price of about \$20 per square meter for material that is 12 mm thick. All the parts leading up to the tongue and groove steps could be readily accomplished in the field with traditional small sawmill equipment. However the tongue and grooved process requires an expensive sophisticated machine with 4 very well constantly aligned cutterheads to produce the

same pattern. As these cutterheads have to be sharpened every 4 hours of operation and reinstalled with the same profile and depth of cut as before sharpening, it is recommended that the field operations produce slightly oversized blanks to be processed at another facility.

(ii) Edge glued panels. Furniture manufacturers normally purchase veneers or panels to produce the fronts, sides and backs of desks, kitchen cabinets, dressers etc. Typically these components are purchased in standard sizes and are not larger than 1 m by 1 m. With today's modern glues these standard sized panels can be produced by edge gluing shorter, narrower boards. After production of shorter boards from the sawmill located in the field, the boards would have to be planed or straight lined ripped (a special saw that produces a very true cut) to produce a perfectly level surface that could be glued to another perfectly level surface. After all the small boards had their edges made perfectly straight, they would be edge glued and placed in an inexpensive press. While this process would not be economically feasible in developed countries due to labor costs, it could be an excellent option for developing countries with inexpensive labor.

(iii) Finger jointing. In developing countries, the high labor costs involved with installation of products such as crown moldings, door trims, and flooring, makes the availability of long clear pieces of wood highly desirable. Fortunately machines are available to produce finger jointing, in which the ends of boards are cut in a serrated form and then glued together to form long pieces. One Texas firm is currently purchasing 8 ft long finger jointed flooring *Prosopis* flooring made in Mexico. Due to the fact that *Prosopis* finishes exceedingly well, a high-speed molder could produce exceptionally attractive molding from finger jointed *Prosopis*.

(iv) Direct manufacture of small furniture components. In contrast to the need to produce long pieces for molding and flooring installation, a U.S. Forest survey of furniture manufacturers found that 90 % of all kitchen cabinet components were less than 75 cm long and less than 15 cm wide. Thus the authors of this study (Araman et al., 1982) suggested short, small diameter logs be used to directly manufacture the sizes required and not first attempt to produce standard sized boards 2.2 m long and 30 cm wide. These authors suggested that most furniture components could be grouped into a standard set of size classes that would meet the majority of furniture manufacturing needs. Thus coordination with furniture manufacturers to bid on supplying a x quantity of y dimensioned wood would greatly assist the furniture manufacture and provide better utilization of the resource.

**D Killing trees.** The 4 basic ways to kill *Prosopis* are (1) fire for small diameter trees, (2) cutting the taproot below the crown, (3) herbicides such as triclopyr and clopyralid and (4) applications of fairly large quantities of used motor oil to the base. Insect biological control against the seeds has been attempted in South Africa but has not been successful. In contrast to other herbivores in which more than 50 % of excreted seeds germinate in the feces, no germinated seedlings were produced from the excrement of wild hogs that consumed *Prosopis*.

On extensive areas in the United States the only treatment with 100 % kill on large areas is cutting the root below the crown with a blade pulled behind a bulldozer. Herbicides applied over large areas are effective in greatly reducing the density, but

rarely kill all of the trees due to variability in environmental conditions. Badly managed aerial herbicide applications may produce half-killed trees that produce many new resprouts.

A new method in the United States is herbicide application (triclopyr/clopyralid mixtures) with a backpack sprayer to kill individual trees (McGinty and Ueckert, 1995). Either a low-pressure stream of these herbicides in diesel fuel is applied to soak a 7 cm long section of the main stem or a water-based mixture is applied to the entire foliage. This is most effective when the trees are less than 2 m tall. This method has the advantage that it could be used to in a dense stand to thin trees to prescribed spacings. Thus if a recent stand of *Prosopis* occurred with an average spacing of 2 by 2 meters, basal herbicides applications could be made to kill alternate trees to bring the spacing to 4 by 4 for example.

At least in the case of South Africa, the costs of the most effective herbicides triclopyr and clopyralid was approximately equal to the value of the land and thus not economically feasible. In a recent review of US efforts to control *Prosopis* where it was a weed (Bovey, 2001) none of 5 options of mechanical and weed control using various partial or entire clearing options, achieved the desired internal rate of return of 8% for cattle grazing. However none of these options included production of significant hardwood lumber component. The most economically feasible control method in developing countries may be hiring labor to dig around the tree and sever the tree below the root crown.

Given the lack of effective techniques to kill trees that applicable on large scales and also economically feasible, it would seem prudent to focus on integrated management using pruning, thinning, replacement with less weedy varieties, developing markets for all products and using herbicides and mechanical techniques to kill individual trees in strategic locations or in thinning operations.

In summary, in locations where *Prosopis* does not exist, under no circumstances should genetically untested materials be introduced for reforestation programs. Only with very serious thought, deliberation and with adequate safeguards, should genetically evaluated material be introduced into areas where *Prosopis* does not exist. In areas where *Prosopis* was present and has been cleared, an annual maintenance program of disking, spot herbicide treatment or excavation to prevent re-invasion will be required. In areas where *Prosopis* is firmly established it will be necessary to initiate an integrated program of utilization, genetic improvement, and management by pruning, thinning and selective killing in strategic locations.

## **II Genetic improvement (replacement with better varieties and clonal propagation).**

As opposed to countries like Argentina and Peru where *Prosopis* is native or to India where the introduced *Prosopis* (In addition to India's native *P. cineraria*) has been extensively studied, the *Prosopis* that has been introduced to Ethiopia has not been well characterized, or at least the characterization has not been reported in the international literature. The scant literature that is available from nearby Eritrea (Habte, undated) and Somalia Zollner, (1986) respectively suggest that the same general *Prosopis* species is present in Sudan (Bristow, 1996), Somalia, Eritrea and



Ethiopia. *Prosopis juliflora* has also been a part of agroforestry projects in the Niger (Butterfield, 1996), Senegal (Diagne, 1996), Haiti (Lea, 1986) and India (Varshney, 1986). The report by Abdel Bari (1986) on the identity of the common mesquite (*Prosopis* spp) in the Sudan was produced to clarify the taxonomy of the major *Prosopis* species in the Sudan and surrounding areas, but unfortunately has a major error that adds confusion to *Prosopis* taxonomy in east Africa. This report has photocopies of the leaf structures of various *Prosopis* Felker took to Sudan in 1980 to establish a *Prosopis* improvement trial. The photocopies include *P. chilensis* 0009 an excellent typical specimen of the species *P. chilensis*. However, this author changed the species of 0163 from *P. alba* as supplied by Felker to *P. chilensis* and this created sufficient variability in the species to be able to include the local *P. juliflora* in this range. Unfortunately, seed from the Sudan was evidently supplied to the regional FAO trials as *P. chilensis* when it was really *P. juliflora*. Felker has visited native ranges of the frost resistant sub tropical *P. chilensis* in Argentina and Chile and clearly the cold resistance, leaf, stem, thorn and pod morphology of the *P. chilensis* from Argentina and Chile are totally different from what this report has called *P. chilensis* in the Sudan (which is probably *P. juliflora*).

In an evaluation of a broad range of 8 tree/shrub species for a sand dune stabilization project in Somalia, Zollner (1986) reported that 5 *Prosopis* species planted out-performed all others in ease of establishment in the nursery and growth and survival after planting and that the local *P. juliflora* was the best performing of all.

Over the last 15 years major advances have been made in the genetic improvement of *Prosopis* varieties that are adaptable to the semi-arid/arid areas of the true tropics such as Ethiopia. Field trials in Haiti, (Wojtusik et al., 1993), Cape Verde (Harris et al. 1996) and India (Harsh et al., 1996) comparing the survival, form and growth rate of *P. alba*, *P. nigra*, *P. flexuosa* and naturalized *P. juliflora* to seeds from the same sources of *P. pallida* in Peru found that the Peruvian selections were the most erect, fastest growing and had small spines. In addition, these Peruvian selections were of the type that are highly palatable to humans and from which many human food preparations are made (see chapter by Grados and Cruz (1996) and in [www.tamuk.edu/webuser/symposium](http://www.tamuk.edu/webuser/symposium)). Based on these most encouraging results Alban et al., (2002) evaluated the form, diameter at breast height, pod production and pod palatability of 1800 *Prosopis pallida* trees in a 10 year old plantation in Piura, Peru as can be seen in Table 1

Table 1. Frequency distribution of pod production, pod flavor and form for *Prosopis juliflora/pallida* trees with diameter at breast height > 20 cm (3.7% of the 1800) in 1999, Piura, Peru.(Alban et al, 2002 Agroforestry Systems in press)

	Percentage of trees with diameter > 20 cm diameter at breast height.				
Percentage of branches with pods.	0% with pods	25 % with pods	50% with pods	75% with pods	100 % with pods
	44.8%	16.4%	8.9%	7.5%	22.4%
Pod flavor	Very bitter	Bitter	Sweet	Very Sweet	
	17.9%	59.7%	7.5%	14.9%	
Form	Weeping	Intermediate	Erect		
	17.9%	61.2%	20.9%		

This shows that even in the center of biodiversity in Peru, the majority of the trees have pods with a bitter or very bitter flavor, that about 30% had high pod production and that only 20% had an erect habit. Therefore there is little wonder that the *Prosopis* that were introduced into Ethiopia by defecation of seeds from grazing animals at worst or by non-scientists at best, were not good quality germplasm. The previously introduced germplasm evolved for adaptability but no other characteristic. Based on all the above desired characteristics the seven trees in Table 2 were selected and then grafted onto common rootstock to provide propagation material for rooted cuttings and budding.

Table 2. Characteristics of the seven elite 10-year-old *Prosopis pallida* clones selected in Piura, Peru.(Alban et al, 2002 Agroforestry Systems in press)

Plot, column, row	Pod production rank	Pod flavor rank	Form rank	Total height (m)	Height to first fork (m)	Canopy diameter (m)	Diameter at breast height. (m)
P4C15R2	4	Sweet	3	10	1.1	10	0.36
P6C6R3	4	Sweet	3	10	1.3	8	0.32
P6C1R12	4	Sweet	3	10	1.7	8	0.21
P8C13R2	4	Sweet	3	10	1.6	9	0.27
P9C2R2	4	Very sweet	2	9	1.1	10	0.23
P5C3R8	4	Very sweet	2	10	1.2	8	0.23
P1C14R9	4	Very sweet	2	8	0.8	7	0.24

The pod production (0= none & 4 = maximum), pod flavor (very bitter, bitter, sweet, very sweet) and form (1= multiple branched, 2=intermediate and 3= single trunk to 1.2 m in height and branch angles < 30°) were ranked as described in the materials and methods.

A greenhouse mist propagation system established in Piura, has routinely obtained high success in rooting cuttings from rapidly growing greenhouse stock plants and there does not seem to be any technical barrier to commercial asexual propagation of these species. In contrast side by side comparison of rooting under mist of *P. pallida* to select *P. alba* clones in Argentina found that *P. pallida* gave virtually 100% rooting while *P. alba* clones ranged from 10 to 70% rooting.

Argentine greenhouse trials examined the growth of Argentine *P. alba* and Peruvian *P. pallida* as a function of increasing salinity using hydroponic systems to ensure that *Prosopis* roots were entirely exposed to the saline nutrient solutions. All Peruvian *Prosopis* were found to grow luxuriantly up to salinities of 15 dS m<sup>-1</sup> and selected clones grew at 45 dS m<sup>-1</sup> which is the same salinity as ocean water. Even a salinity of 15 dS m<sup>-1</sup> is more than 10 times greater than most annual crops can tolerate. The tantalizing possibility of growing *P. pallida* clones, that grew in 45 dS m<sup>-1</sup> NaCl in Argentine greenhouse experiments, with water equivalent in salinity to seawater should be explored.

While there is some fear that clones will be unduly susceptible to plagues and diseases, economically attractive investments into *Prosopis* forest industries will require uniform, high lumber productivity stands with high productivity of quality complimentary products such as pods. This in turn will require a substantial narrowing of the germplasm base in the choice of elite clones or seeds from trees of proven performance, such as is the case with eucalyptus, populus or pines.

### **A Applied research**

Procedures should be implemented immediately to obtain by air courier rooted cuttings of the 7 elite multipurpose clones from Peru and several of the *P. pallida* clones selected in Argentina that grew at seawater salinities.

A greenhouse mist propagation and grafting facility needs to be established (similar to one Felker designed in Peru) to efficiently propagate these elite materials. This system will include a drip irrigation for the greenhouse grown stock plants to efficiently produce large quantities of insect and disease free cuttings for propagation, a mist system with bottom heat, and a backup system to compensate for power and water outages. This propagation facility will also serve to produce scions and budwood to graft coppice growth of harvested stumps and a micro tunnel system to graft young 2mm diameter wild seedlings to be produced for pod producing stands.

A second "shade cloth nursery type facility" should also be established seeking to find simpler, more cost effective systems to produce rooted cuttings and grafted seedlings than a somewhat high tech greenhouse system.

This advanced greenhouse propagation system should also be used as a teaching facility for university horticultural and forestry students.

Once rooted cuttings have been produced they need to be evaluated in well-replicated regional trials using the "naturalized *P. juliflora*" as a standard. These stands need to be evaluated for growth rate, pod production (visually ranked according to defined standards), pod flavor, spine characters and form. Inferior clones or naturalized seedlings need to be rogued after about the 6<sup>th</sup> year to produce a seed orchard. This plot should also serve to demonstrate the qualities of the elite clones and to provide scions for grafting and seeds for nurseries.

If the annual evaluations of the comparison of elite Peruvian *Prosopis* proves to be superior to the naturalized *Prosopis juliflora* for any or all characters, the clones will need to be distributed in the extension program described below.

### **B Extension, demonstration and training**

The extension programs with regard to genetic improvement need to emphasize that as there are many differences in strains of maize, beans, and people, so there are differences among various *Prosopis* trees. Thus genetic improvement programs can lead to large increases in production of pods, in pod quality and in form of the trees. While it is impractical to provide training on rooting of cuttings at the village level (due to the requirements for strict control of environment of stock plants, mist etc) it

would be worthwhile to provide budwood of the elite 7 clones and training on grafting this budwood.

It is recommended that about 6 to 8 centers be established in representative arid zones where *Prosopis* is common to: routinely demonstrate techniques for grafting onto 35 day old seedlings and coppiced resprouts from mature trees and to provide scions of the superior clones. These centers might well be attached to existing agricultural centers for other crops or services.

### **C Large scale implementation**

The decision to implement large scale distribution of the elite *Prosopis* clones will depend on the superiority of pod production, pod taste characteristics, lumber production and form/spine characters over the indigenous *P. juliflora*. Obviously with the periodic droughts in Ethiopia that severely negatively effect food production from conventional cereal crops, if these clones prove to have significant production of pods that are highly palatable to humans, the clones would be of great value. As noted above, pod production is usually greatest in drought situations when rain does not disrupt the pollination process and when the plant is under stress.

If large-scale distribution of improved germplasm is deemed to be politically and socially beneficial, a government implementation route would be appropriate for pod production purposes and a private sector implementation route would be appropriate for the commercial lumber objectives. For the pod production purposes, a major campaign with extension agents distributing pamphlets, budwood, grafted seedlings and holding workshops would be appropriate.

For the commercial lumber production emphasis, it is important to note that a significant portion of Ethiopia's arid zones have rainfall in excess of 600 mm per year that is required for commercial lumber production solely based on rainfall. If annual diameter growth rates likely to be commercial (on the order of 1.2 cm per year in diameter) which would lead to rates of internal return of the order of 10%, then investors could be sought to establish commercial plantations. In this latter case both plantations and genetic enrichment of native stands by grafting elite scions onto resprouts from harvested trees would be possible.

## **III Plantation establishment and management**

### **A Applied research**

Due to the problems with *Prosopis* as a weed in Ethiopia, the decision to produce more *Prosopis* in plantations will undoubtedly be questioned. However once the superiority of newer genetic materials is demonstrated and the potential food impact from pod producing varieties and the potential economic impact from management from hardwood lumber is demonstrated, it is envisioned that a significant need for new plantations will arise.

The most important factors in both hand planting and mechanized plantations are: (1) weed control and soil working the rainy season prior to planting to achieve field capacity in the soil profile, (2) the need to plant 4 month old seedlings a minimum of 50 cm tall and 4-5 mm in diameter in long (25-30 cm) narrow (3.5-4.0 cm) containers

to facilitate development of a tap root and (3) the need to provide intensive weed control a minimum of the first 3 years after establishment. Note that irrigation at the time of planting is not listed above since 1 mm of stored soil moisture is equivalent to 10, 000 liters of water per ha and since with proper site preparation irrigation at transplant does not provide any additional benefit. The needs described above can be met by soil working (hand or tractor) or herbicides. If available, herbicides can be especially helpful to reduce weed growth during high rainfall periods when the soil is too wet for cultivation and when the weed growth is most intense. Intercropping *Prosopis* (on spacings such as 10 m by 10 m) with annual plants is an excellent system since annual plants do not provide great competition to *Prosopis* and since the weed control of the annual crops also benefits the *Prosopis*.

With regard to the nursery techniques two factors are critical; one to grow the seedlings in a suspended system with open bottoms and second to inoculate with rhizobia specifically adapted to *Prosopis* such as strain number 133-z-1 from Nitragin in Milwaukee, Wisconsin. This rhizobia has been shown to very effectively nodulate 13 *Prosopis* species and to have much greater salt tolerance than common rhizobia species. By a suspended system it is meant that the seedlings are grown in cardboard or plastic bag containers with open bottoms in wooden or plastic crates so that a 1-cm air layer is present between the bottom of the container and the soil. This stimulates root pruning at the bottom of the container and avoids spiraling in the root container. This means that the seedlings have to be irrigated in the nursery from above and not by flood irrigation in pits as is common in most nurseries.

Surprising as it may seem, weed control is absolutely critical to the establishment of *Prosopis* plantations. For example rainfall totals greater than 300 mm during the first season of establishment have stimulated vigorous competition from herbaceous vegetation that has reduced survival by 30 to 40% and decreased growth by 300 % for even large, well developed seedlings (with 40 and 80 cm long root and shoots respectively) (Felker et al., 1986). Therefore combinations of mechanical weed control by hoeing, animal traction, tractors and inexpensive herbicides such as treflan, surflan, linuron and diuron are vital to establishment of plantations that have high survival (95%) and rapid growth (> 1.2 cm diameter per year).

Due to the availability of Peruvian clones with very high resistance to salinity (45 dS m<sup>-1</sup> = seawater) it would be highly recommended to establish trials on saline soils (< 50 dS m<sup>-1</sup>) and using irrigation water from sources of equivalent salinity to ocean water.

Due to the ease with which the elite Peruvian clones can be rooted, plantations from rooted cuttings are possible. Visual inspection of 4-month-old plants from rooted cuttings shows that they have a much more extensive root system that one derived from seeds and it is this authors experience that one of these fibrous roots always develops into a taproot as well.

Should the opportunity arise for large scale mechanized plantations, for either lumber or pod production, descriptions of heavy duty tree transplanters, subsoiling systems, combinations of mechanical and chemical weed control and fertilization are available ([http: Prosopis.url4life.com](http://Prosopis.url4life.com)) (Felker et al., 1989)

## **B Extension, demonstration and training**

At the 6 to 8 representative sites where the improved germplasm will be made available it would be most useful to also install demonstration trials comparing seedlings grown with and without suspended root systems and with and without weed control the year prior to planting to achieve soil field capacity and mechanical and chemical weed control the first 3 years after planting. In a nearby farmers field it would be useful to have an on farm demonstration of the inclusion of the elite trees on wide spacings(10 by 10 m) grown in an annual intercropping scenario.

At one location in Ethiopia where the rainfall is equal or greater than 650 mm per year or where groundwater is less than 3 m from the surface, it would be very beneficial to install a small plot (1-2 ha) to demonstrate completely dryland but mechanized plantation establishment and maintenance to serve as an example for the potential large investor who may be interested in commercial lumber or pod production from *Prosopis*.

### **Large scale implementation**

Large scale implementation of *Prosopis* plantings should not be envisioned until evaluations of the trials of the clonal material vs. the naturalized *Prosopis juliflora* are known about 3- 4 years after the trials are initiated. Large-scale implementation of *Prosopis* plantings will also depend on the success of the efforts to develop domestic and international markets for human food use products and lumber, flooring, and furniture products. About 4 years after these parallel initiatives have been underway, it would be most useful to conduct a supply/demand marketing study for the various products to determine if a significant initiative in plantings was warranted. At this time both the types of plantings and the end uses; pods vs. wood, small farmer interplanting vs. large scale commercial planting should be evaluated to develop a national resource development management strategy. If the indicators were positive it would be appropriate for the government to actively seek private investors and the participation of small growers rather than participating directly in the establishment and management of the plantations.

## **IV Natural stand management, thinning, pruning, understory removal, in situ genetic improvement by grafting onto resprouts and estimation of standing sawn lumber.**

### **A Applied research**

The little work that has been done on silvicultural type management of native *Prosopis* stands has demonstrated 3 to 4 fold increases in growth rates with treatments such as thinning pruning and P fertilization (Patch et al., 1997a,b). This is not surprising as these standard treatments also dramatically increased the growth rates of traditional, well-studied temperate hardwood stands.

Due to the weedy nature of *Prosopis* in some locations in Ethiopia, it is indeed fortunate that the management of existing *Prosopis* stands for useful products such as pods, lumber and firewood is coincident with the management of *Prosopis* of the *Prosopis* weedy stands. Due to the critical need for firewood, it should be possible to

have the natural stands thinned and pruned, without cost, by allowing the people to harvest firewood. However the trees to be harvested and the branches to be pruned must be very carefully specified. Dense stands ( $> 10,000$  stems/ha) of small diameter ( $< 5$  cm) *Prosopis* have been reported to contain up to 60 tons/ha of biomass (Felker et al., 1990). Since only several hundred stems per hectare are desirable from a silvicultural point of view, the harvest of more than 95% of the biomass for fuelwood is highly desirable. However the harvest needs to be prescribed by spacing and percentage of branches removed from "crop trees" and cannot be random.

Treatments such as pruning to single stems, removal of understory, thinning, and P fertilization needs to be examined. For dense stands of small trees (ca 10,000 stems less than 5 cm in diameter) the thinning could be to spacings of 5 by 5, 5 by 10 or 10 by 10 meters. If stands of large diameter trees exist (mean diameter  $> 14$  cm), the thinning could be done to eliminate about 30% of canopy closure, to convert multiple stemmed trees to single stemmed trees and to prune trees to single stems up to 1.5 to 2.0 m in height.

The experimental design should include 4 replicates in a randomized complete block design and the individual replicates should be large enough to contain 15 to 20 trees. In the low rainfall sites, the replicates will occupy a greater surface area than in the high productivity sites. For the mature stands of large diameter trees, it is recommended that the diameters of all trees be measured, that the trees be stratified according to size class and that about 20 % of all trees be fitted with inexpensive (\$2 each) dendrometers to be able to detect and accurately measure the small diameter increases in growth (1 to 3 mm/year) that often occur in overstocked *Prosopis* stands. From these diameter increases, regression equations can be developed to measure increases in both volume and biomass. From the increased growth, and the costs of the treatments, the economics of the treatments can be calculated.

It will be important to develop techniques to measure the volume of all potential products from *Prosopis* native stands. A 20-cm trunk diameter size class is the point at which small log sawmills can begin to produce high value lumber, flooring and furniture parts. To estimate the biomass present in trees below 20 cm that can only be used for charcoal and firewood, it will be necessary to harvest about 50 trees ranging in diameter from 2 to 20 cm in diameter and to; weigh the trees fresh and after drying, to measure the basal diameter and to compute log-log regression equations between basal diameter (diameter at breast height is not practical due to multiple branching) and fresh and dry biomass.

For trees larger than 20 cm in diameter it will be necessary to determine the quantity, quality and length/width relationships of lumber small log sawmills for trunks less than 35 cm and for log diameters greater than 35 cm using conventional circle or band saw mills. It is suggested that about 40 trees representing the full range of basal diameters greater than 20 cm be harvested, carefully sawn into lumber and the length/width of each board be measured and then summed per tree. For 40 trees a regression of lumber volume vs tree diameter will have 38 degrees of freedom and will be sufficient to predict the approximate sawn lumber volume and value of *Prosopis* stands of larger diameter.

In situ grafting of shoots from coppiced stumps needs to be examined using scions possessing superior characteristics of form, growth rate and pod characters as noted in the genetic improvement section. Variables to be researched would include the presence/absence of small shades over the grafts as illustrated in Figure 3, grafting in various seasons of the year and graft sizes. It would be of obvious great benefit if weedy non useful *Prosopis* stands could be converted to commercially valuable stands by taking advantage of in-situ grafting onto coppiced shoots, which by virtue of their extensive root system have much more rapid growth than seedlings.

### **B Extension, training and demonstration.**

The extension programs on the management of existing stands will need to be coordinated with the extension program on control of the weedy aspects of this species. Due to the extensive nature of the *Prosopis* stands it will be necessary to establish 4 or 5 research/demonstration plots in areas that have been chosen to represent typical problem/opportunity stands and also that are close to major population areas. If possible each site should be located where both the management of dense small diameter stands (< 5 cm stems with more than 10,000 stems/ha) occur and where stands of larger mature trees (> 16 cm diameter occur). In many other locations in the world, these dense, small diameter stands often occur in abandoned city lots or on communal lands along railways and highways. If government approval could be obtained to gain permanent and controlled access to sites such as these, they would provide very high visibility access to these new techniques. Several field days each year should be scheduled to demonstrate the research plots where the thinning pruning and management is being conducted. Tours of these plots should be arranged for university and school children who will be responsible for the stands in the near future. Brochures with photographs on multiple use management of the native forests should be prepared and distributed in cooperation with local political units and with the Ethiopian Agricultural Research Organization.

### **C. Large scale implementation.**

On private lands, it will be necessary to produce information showing the economics of good management. As the sale of the thinnings and prunings in the form of valued added lumber products, firewood, and posts probably will cover the costs of the thinning there will be every incentive to properly manage these stands

The issue of management of the existing native and/or weedy stands on abandoned private or communal lands is the greatest problem due to the greater percentage area where this occurs. Obviously it will be difficult to institute management of communal lands by thinning small diameter trees to larger trees if at any time, the remaining valuable trees can be harvested by anyone. Thus it seems necessary for the government to be able to grant long term concessions to manage the native *Prosopis* forests by thinning and pruning. This is not to say that poor people will no longer be permitted access to these stands for fuelwood collection, but rather this fuelwood collection and harvest will be conducted according to prescribed methods to both reduce the weedy issue and to improve the value of the stand for larger timber sized products. This will also require development of a semi-arid forest inspection team that will prescribe the sizes of trees and branches that are permitted to be selectively harvested.



## V Firewood issues

Due to the fact that 75% of all of Ethiopia's energy is derived from fuelwood, that the shrub and woodlands contain the vast majority of the stock of fuelwood (Tables, 4,5) and that *Prosopis* produces fuelwood in the most difficult arid sites, the management of *Prosopis* for fuelwood can fulfill a most important need in Ethiopia. For example, since dense stands (5000 stems/ha) of small diameter (mean 5.5 cm diameter) *Prosopis* in Texas (Felker et al., 1990) contained 75 tons of fresh biomass per ha and since > 95 % of this biomass needs to be harvested to concentrate the growth on the remaining trees for high value lumber applications, a one time thinning of such a stand would provide approximately 70 tons of *Prosopis* per ha of fuelwood.

Due to the low value of firewood and the inability of poor people to pay for firewood, *Prosopis* plantations for firewood would not be profitable as a private sector initiative. However if sufficient fuelwood is not available in certain arid areas, cities could establish plantations for *Prosopis* firewood and give permits to people below a threshold income to harvest firewood for their own needs. Alternatively, where *Prosopis* has become naturalized on undeveloped city lots, local governments could provide tax incentives to the owners of the undeveloped lots to allow people below certain income levels to harvest firewood. Owners of commercial *Prosopis* plantations destined for high value lumber or pod uses, could make arrangements for the pruning and thinning of the plantations to be conducted in exchange for the firewood that is harvested

Perhaps firewood from *Prosopis* is most properly viewed in the "emergency relief" category that is necessary for governments to subsidize and manage while medium to long term programs for lumber and pod industries are developed that can provide sufficient fuelwood as a by product of thinning and pruning operations.

## VI Development of human and animal food uses of *Prosopis* pods

With regard to developing the human and livestock food uses, it will be important to initiate a program to collect the pods immediately after they have fallen from the ground, and to dry them to 6% moisture in a solar or wood drier so they can be ground. If the pods are not dried, the heat resulting from the grinding process will react with the sugar and water to form a cement-like mixture that will adhere to the grinding mechanism and cause the grinder to come to halt. Examples of the coffee drier, wood fired heat exchange and grinding system developed by Mr. da Silva of Brazil are shown in Figures 4, 5, 6 and 7. For animal food uses it is best to grind the pods as this will release the protein in the hard seed coat and prevent whole scarified seeds from being defecated in the feces to germinate and spread in an uncontrolled manner over the landscape. Unlike processing for human food applications where it is desirable to produce various fractions by sieving, this is not necessary in animal feed applications. Various trials have shown, not surprisingly, that the ground pods cannot be used for 100% of the diet for extended periods of time (Abdelgabbar, 1983) but when ground pods were mixed with cotton seed cake and wheat bran so that ground *Prosopis* only constituted 70% of the diet, the goats gained weight.

Mr. Da Silva's system for drying and grinding *Prosopis* pods.



Figure 4. Wood fired heat exchanger on outside of building.



Figure 5. Rotary coffee dryer with heat provided by wood exchanger

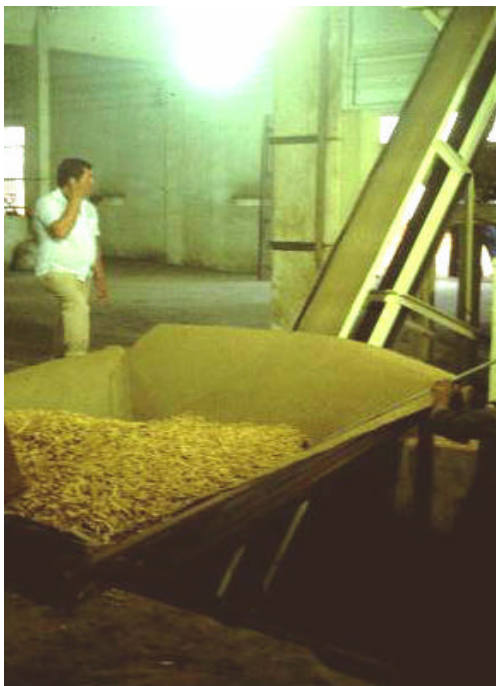


Figure 6 Hopper containing dried & broken pods



Figure 7. Hammermill and bagging system for the ground *Prosopis* flour.

When the pods are to be used for human food, an additional washing step for the pods and a series of screening steps are necessary to produce a refined flour most appropriate for human food use. The equipment used to produce value added human food products could range into the millions of dollars. A complete plant layout to produce 1 ton of *Prosopis* pod flour has been described in detail by Saunders et al., (1986) and Meyer (1984). However the simplest and most economical set of equipment needed to get started in *Prosopis* human food products is as follows: (1) A 1 m by 4 m table to sort the good pods from the bad insect infected ones, (2) about four 20 liter buckets containing clean water to briefly dip and wash the pods to remove gross contaminants, (3) several 1.2 by 4 m tables with woven wire surfaces to allow the washed pods to air dry, (4) an oven with multiple racks heated by solar energy or by a heat exchanger from a wood furnace. The oven temperature needs to be about 55 C and have circulating air. The pods will take 4 hr to dry in a 55C oven with air circulated by a fan or 12 in a static oven with no circulating air. (5) A hammermill with an 8 mm sized screen that will allow the flexible endocarp portion to pass intact, and thus be easily separated from the fine mesocarp pulp by screens, (6) a 20 mesh screen that will retain the large endocarp portion while allowing fine mesocarp particles to pass, and (7) a second abrasive type mill that will regrind the mesocarp portion that passed the 20 mesh screen, (8) an 80 mesh screen that will be used to provide the final sieving. The 80-mesh flour which results in yields of about 42 % by weight from the pods can be used as the starting material for many food products. The large flexible endocarp portions can be ground for animal feed or extracted to produce syrups.

In developing the human food uses of *Prosopis*, it is important to recognize that while the current *Prosopis juliflora* pods in the horn of Africa contain sucrose, they are somewhat sour or astringent and much less palatable than really good Peruvian *Prosopis pallida* varieties (Felker unpublished obs). Thus it will be important to upgrade the palatability and production of the pods through introduction of Peruvian *P. pallida* that have been selected for high pod production and pods with a palatable sweet flavor as described in Section II Genetic improvement.

It would be useful to compare the taste and consumer acceptance of the flour of the Peruvian *Prosopis* as compared to that of the local *P. juliflora*. For this purpose it would be useful to contract with the team at the Universidad de Piura to provide about 500 kg of the Peruvian *P. pallida* flour to be used in comparative taste tests and in trials with local bakeries. As the taste preferences of Peruvians and Ethiopians are quite different, Peruvian recipes may not appropriate and it would be best to incorporate the Peruvian flour in Ethiopian pastry products in the 10 to 25% range. While university and Ministry of Agriculture food technical people need to be involved in these tests, the leadership and evaluation should be from private sector bakeries and chefs as they are in more close touch with the day to day trends in the food industry.

In the introduction of Peruvian varieties for pod production, very low rainfall areas (<100 mm/yr) with underground water within 4 m of the surface would be most appropriate. This is because considerable unpublished observations suggest that locations where no rain or winds are present during flowering, have much greater and more consistent year to year pod production than areas where rain and wind occur during flowering.

### **A i Applied research for human food uses.**

Due to the somewhat expensive nature of research equipment involved in the food chemistry area, it is suggested that collaborative applied research on *Prosopis* pods be conducted in collaboration with other research units that are active in *Prosopis* food products such as the Universidad de Piura, Piura, Peru, the Universidad Nacional de Santiago del Estero, Argentina and other food research groups in Europe and the USA.

The protein, fatty acid, carbohydrate and galactomannan gum content of various *Prosopis* pod fractions has been well documented in the scientific literature and there is no need for additional research in these areas.

In Ethiopia, various products from *Prosopis* pods could be consumed in combination with other traditional foodstuffs to offset food shortages and various pod fractions could be processed into high value products to be sold nationally and internationally to generate revenue to purchase other necessities. For direct consumption, it would be important to conduct research to develop recipes compatible with other traditional foods using staple cereals such as teff and barley. In these applications it would be important to realize that the basic properties of *Prosopis* are: a high energy content due to the 45 % sucrose in the flour, an average protein content (ca 9 %), and a lack of gluten which leads to decreased bread volume. However, Meyer (1984) has demonstrated that addition of 1-% guar gum to *Prosopis*/wheat flour mixtures greatly improves the bread volume. Since "tortilla-like products" using the traditional cereal teff are common in which bread volume is not an issue, *Prosopis*/teff combinations should be investigated.

Due to the rapid infestation of *Prosopis* pods by bruchid insects, applied research on sanitation should be a priority for both direct consumption and national/international markets. Recent Argentine research has found that an initial milling using an 8 mm screen prevents the milling of the leathery capsule containing the seed (endocarp) and thus permits the rapid separation of this capsule from the remainder of the pod mesocarp- which is the most valuable fraction for human food. Since the bruchid insects are in the seed, which in turn is inside of the leathery capsule, this fractionation provides rapid separation of the insect contaminated pod portion from the remainder of the pod.

To date no information exists on typical composition of insect eggs, larvae and parts, bacteria, mould, mycotoxins or filth that exists in *Prosopis* flour, acceptable levels of these components, or management techniques that can be used to reduce the levels to acceptable concentrations. In the development of a sanitation system for quality control in production of *Prosopis* flour for human use it will be very useful to consult the FAO Bulletin "Quality Assurance for small-scale rural food industries" [www.fao.org/docrep/V5380E/V5380E06.htm](http://www.fao.org/docrep/V5380E/V5380E06.htm). This is based on quality control, microbiology and risk management to identify sources and routes of contamination by microorganisms, biological, and chemical or physical contaminants

For the national and international markets, the value of *Prosopis* flour will reside in the aroma and taste properties, which are in the same general class as

cafe/cacao/cinnamon/mocha rather than any benefit from textural properties. These aroma/taste properties reside in the pod mesocarp, which constitutes about 45 % of the pod by weight. As a general rule, this flour provides best consumer acceptance when used in the 12 to 18% range of total product weight. At this low percentage it should be possible to compete in price, not against traditional wheat flour, but with specialty products such as cacao, cinnamon, carob flour etc. For these national and international markets, it will be necessary to ensure uniformity in sensorial analyses among batches. While the proximate composition of pod mesocarp flour changes little between batches, there is considerable variability in astringence and flavor. For example as noted in Table 1, only 23% of the Peruvian trees that were acceptable for form and growth rate had pods that were sweet or very sweet. To date this is an area that is virtually unresearched, although some work has been initiated on this topic at the Universidad Nacional de Santiago del Estero, Argentina.

A recent economic analyses (Felker et al., 2002) found that the most important factor in determining the price was the yield of flour from the entire pod weight. For example using Argentine labor rates, the flour price went from \$4.75 kg<sup>-1</sup> to \$1.81 kg<sup>-1</sup> when the yield of flour as a percentage of the flour to whole pod changed from 10% to 45%. Since Argentine researchers have been able to achieve this yield, but Peruvian researchers have had difficulty achieving this yield, Ethiopian R&D into maximizing pod flour yields would be an important priority.

Other important applied research issues for human food uses that remain include;

- (1) Marketing research for various products both nationally and internationally,
- (2) More accurate determinations of critical vitamin concentrations such as folic acid
- (3) Improving the rheological properties of bread via addition of guar gum as suggested by Meyer, (1984),
- (4) Taking advantage of the anti-rancidity properties of *Prosopis* flour described by Meyer (1984).

## **A ii Applied research for Animal feeds**

*Prosopis* pods are a very good source of livestock food and are often available in dry areas where little other livestock feed is available. Gomez-Lorence (1970) reports rations for many types of livestock using ground *Prosopis* pods in Mexico. As the 35% protein seed has a very hard seed coat that is not broken or digestible by ruminants, the greatest benefit for livestock feed can be derived if the pods are ground to release the protein in the seed. If the pods are not dried with an auxiliary heat source to 6% moisture, due to the high sugar content of the pods, a glue like mass will develop in the grinder that with additional heat of friction will solidify into a rock hard mixture that will stop the grinder. Da Silva in Brazil used innovative heat exchangers fired by wood stoves dry pods in rotating coffee dryers. Alternatively, the pods can be fed to the animals as is, accepting the loss of protein in the seed

As Silbert (1986) [www.tamuk.edu/symposium](http://www.tamuk.edu/symposium) pointed out in her evaluation of the performance of the cooperative in Matehuala, Mexico to process *Prosopis* pods for livestock food, the year to year variability in pod production was enormous. For example in 1982, 2800 tons of pods were processed but in 1983 there was an almost total failure of production and the same general trend occurred in 1984/1985 and 1986/1987. In the summers of 1999/2000 and 2000/2001 in Argentina there was an

almost total failure of *Prosopis* pod production over 5 provinces. Thus in good pod production years, the pods could serve for human or livestock food. However it is not something that can be counted on and should be considered a plus and not part of ones "proven reserves or sources of food or income".

Where pod production does occur, in extraordinary good years with high densities (100 trees/ha) of large trees (40 cm diameter), the maximum production probably does not exceed 4000 kg/ha. In most years a really good production would be 1000 kg/ha for a complete canopy closed system. Most years the production would be on the order of several hundred kg of pods/ha.

It is this authors perspective that the year to year variability and resource issues are more problematic than the development of appropriate feed rations. Land tenure issues also become involved. If the pods are collected from state lands, lands of absentee owners or common lands without a return to the landowner, no resources can be devoted to management and thus the system cannot be sustainable. However, if a landowner has large native stands he could begin to manage these stands to increase productivity by thinning, pruning and introduction of beehives to increase fruit set in this obligately outcrossed species.

Perhaps some of the year to year variability problems could be resolved with newer varieties, reduction of stress from neighboring competition, planting along sites with permanent underground water etc. If *Prosopis* plantations were established using new genetic materials, possibly less variability and higher production would occur. Given final selling prices of about \$120 per ton for ground animal feed and long term average yields of 1 to 2 ton per ha, pod uses for animal feed could not justify plantation establishment but would be a most valuable byproduct of plantations.

Having issued this warning on the great year-to-year, and tree-to-tree variation in *Prosopis* pod production, it is acknowledged that in some years *Prosopis* pod production could make a significant regional contribution livestock food supplies and that high production is most likely to occur in drought years when other forage and cereal crops fail. Thus it would advisable to be prepared to take advantage of such production when it occurs. This would involve development of rapidly deployable solar dryers (perhaps wide [3m] but short [1 m] tall clear plastic tunnels with a black plastic bottom), gasoline or diesel driven hammermills that can be transported in pickup trucks, and heavy duty plastic bags or sealable drums to store the ground pods. It is to be noted that heavy duty, long life, greenhouse plastic is available in 10 by 30 m dimensions for about \$300 and that 10 mm diameter, steel rod used for concrete reinforcement is usually very inexpensive and could be used to build a low, portable solar greenhouse. Assuming a low bulk density of 200 kg per cubic meter, a 5 cm thick layer of pods, a 24 hr drying time, a useable floor space of 8 by 20 meters, such a structure could dry 1600 kg of pods per day. A small hammermill with a 0.5 kw engine can grind about 100 kg per hour, so that one solar dryer and one small portable mill should be able to produce about 1 ton per day of ground pods. The combination of heat to dry the pods and grinding will destroy the insects and eggs and if the flour is stored in insect proof containers, the flour will have much less tendency to be re infected. As ground *Prosopis* cannot constitute 100% of the diet, other feedstuffs likely to be available in severe droughts, such as forage cactus types, fodder shrubs etc, should be tested as complimentary feeds. In addition, placement of

beehives in *Prosopis* stands should be tested for their influence on stimulating pod production in self-incompatible *Prosopis*.

### **B Extension, demonstration and training**

Extension components will be directed at: (1) the small farmer in the field to provide higher quality pods and minimally processed flour, (2) existing human food manufacturers (bakeries, candy makers, syrup manufacturers and snack food producers) to stimulate market demand, and (3) livestock owners and animal feed providers to be prepared to utilize pods for livestock feed with the greatest efficiency. This will involve one extension team that is knowledgeable of the rural countryside and *Prosopis* stands who will be responsible to work with farmers to coordinate collection of cleaner pods for the human food industry. A second extension team should be fielded to produce flour samples of high sanitary quality for human food uses, and to provide associated technical information to small, medium and large food producing companies with the goal of stimulating the market for human food uses.

### **C Large scale implementation**

A large scale implementation program for both human and livestock uses of *Prosopis* pods, should be permitted to build slowly over several years starting from about a dozen strategically located utilization centers with mobile grinders and plastic tunnel dryers. Addition of a screening system to the grinder and dryer, in order to separate the mesocarp portion from the potentially insect infected endocarp portion, would permit development of flour for human food utilization. With trial and error and gradual provision of ground pods to livestock producers and high quality flour for human food uses, this system should build on itself it is indeed a sound plan. If successful the results should be promoted through regional government and cooperative agencies. The extension agents would facilitate initial meetings between regional government officials, IAR researchers and the extension agents to plan promotional fairs, talks to grower groups, radio, TV and newspaper coverage and information bulletins. See also XI Attraction of investors and IX Development of National and International Markets.

## **VII Applied technology to stimulate value added**

As a simple introduction to the theme of value added from *Prosopis* wood products, it is important to realize that at current US and Argentine *Prosopis* lumber prices of \$2 per board ft (1 bd. ft = 12 inches by 12 inches by 1 inch and 428 bd. ft = cubic meter) sawn lumber has a value of about \$860 per cubic meter or more than \$1000 per ton (at 750 kg per cubic meter). In contrast firewood and charcoal have retail prices of less than \$5 per stacked cubic meter and \$60 per ton respectively. Thus every effort should be made to convert *Prosopis* to dimensional lumber, rather than firewood or charcoal.

It is important to point out that the new National Hardwood Lumber Association grading rules for *Prosopis* specifies that the highest grade of lumber, FAS, need only have minimum dimensions of 120 cm by 15 cm. Furthermore, after finding that 90% of all components for US kitchen cabinets were less than 75 cm long and 15 cm wide, a leading US hardwood research institute proposed (Araman et al., 1982) that small hardwood logs be used to directly produce standard sized furniture blanks, rather than 30 cm wide 2.2 m long boards that would in turn be reduced to the appropriate sizes. For example a chair might be produced from various quantities of less than 10

standard sized components. As less waste and labor would be involved in manufacture of chairs from these blanks, it would seem reasonable that these components would have value at least as great as rough lumber or \$850 per cubic meter for *Prosopis*.

The production of parquet flooring from *Prosopis* is an excellent high value added application as the 3 dimensional stability and hardness of *Prosopis* flooring is substantially better than the most common parquet flooring i.e. oak. Since 12-mm thick flooring has a minimum price of about \$20 per square meter, it has a value of \$1666 per cubic meter or \$2222 per ton. While oversized blanks without the tongue and groove can be efficiently produced by moderately inexpensive sawmills (\$8000 to 25000), the final tongue and grooving can only be efficiently produced by expensive and sophisticated machinery (\$50,000) operated by very experienced personnel. Thus the final tongue and groove process is usually best carried out under contract.

Fortunately in the last 15 years there has been a proliferation of highly efficient portable sawmills (pulled to the field by a pickup truck) capable of converting small logs about 22 cm diameter-50 cm long (normally left in the field or converted to charcoal) at the rate of about 0.4 cubic meter of sawn lumber per hour. Even if only prices of \$400 per cubic meter were obtained for this material, this would yield an hourly revenue of \$160. While the purchase price of one such machine, a Morgan portable Scragg Mill with 2 circular 85 cm diameter blades powered by a 75 hp Cummins diesel engine is about \$21,000, at a revenue of \$160 per hour or \$6400 per week, the equipment could be readily paid for.

In considering the utilization of *Prosopis* wood products in Europe where *Prosopis* furniture products are unknown (unlike the USA or Argentina where *Prosopis* products are highly respected), it would be important to involve a highly respected wood furniture institute such as the Centre Technique du Bois et de L'Ameublement (CTBA) in Paris ([www.ctba.fr](http://www.ctba.fr)). The CTBA has excellent facilities for studies of wood drying, finishing, furniture design and is well connected with the European furniture industry. The Ethiopian plan should include a contract with the CTBA to evaluate the suitability, and potential markets for *Prosopis* interior and exterior wood products in the European Community.

Small but high quality products such as pens, perfume holders, clocks such as can be found in [www.craftusa.com](http://www.craftusa.com) could be very useful in generating income for poor people in isolated rural areas. For example, the mechanism for a Cross pen can be purchased for \$3 and then the necessary wood components turned on a small lathe costing \$400 to make a luxury pen. If this pen were properly marketed in Europe or large capital cities with a strategy that it was produced by poor African farmers it would have a retail price of \$20. If the producer only got \$10, they would net \$7 per pen. In Ethiopia this is equivalent to almost 2 cubic meters of firewood or 70% of monthly income (Per capita income of Ethiopia is \$100 per year).

As illustrated in Table 3 below, a well-equipped woodshop containing \$5500 of the equipment and supplies would be necessary to make articles from supplies obtained at [www.craftusa.com](http://www.craftusa.com). that would have a monthly production valued at \$8000. One of the best USA mesquite craftsmen, Bill Smith ([jayboxes1@home.com](mailto:jayboxes1@home.com)) who is a retired construction contractor would be pleased to perform training sessions for the price of his airfare and per diem.



**Table 3 Characterization of various levels of economic development projects from *Prosopis* wood products.**

	Firewood	Charcoal	Artesanal products		Small furniture components.	Entire furniture manufacture		
			National	International		Village level quality	National level quality	International level quality
Characteristics	Green and dried wood, < 12 cm diameter	Product that results from earthen pits or brick kilns.	Carved & turned articles, small boxes with poor joinery & finish	Turned articles e.g. pens, perfume, holders, clocks with excellent finish and hardware.	Products such as parts for window shutters, chairs, kitchen cabinets.	Crude construction with nails & no joinery	Medium quality with some visible nails, some joinery, < 150 grit sanding, no design input. Wood not kiln dried	High quality, no visible nails, exc quality glue joinery, >180 grit sanding, Wood kiln dried to < 11% moisture. Commercial quality, contract & custom furniture. Could be designed & specified.
Web examples				<a href="http://www.craftusa.com">www.craftusa.com</a>				<a href="http://www.wildlifecollection.com">www.wildlifecollection.com</a> <a href="http://www.hustonandcompany.com">www.hustonandcompany.com</a>
Workers/unit	1-2	Family	2-3	2-3	2-3	1-3	2-15	6-10
Wood resource requirements /month	about 100 kg	15 m3 of wood						500-1000 bf/mo of veneers, 500 sf/mo panels, 30 pcs 4 x 8/mo
Product output/month	about 100 kg	1000 kg charcoal		800 pens/mo or 160 boxes/mo	4000 bd ft of components	One hundred chairs @\$20		
Value of product to producer/month		\$30-50		\$8000	\$8000	\$2000		\$40,000 -\$60,000/mo

Equipment requirements	machete or axe	Shovel & Axe	lathe, table saw, drill press, glue clamps &	lathe, table saw, bandsaw, planer, jointer, router, sander, drill press, glue clamps	sawmill, table saw	Sawmill, table saw, belt sander	Sawmill, table saw, belt sander, glue clamps, drill press, shaper, paint brushes,	Saws, planers, sanders, glue clamps, drill press, shaper, jointers, routers, compressor, spray gun for finishing
Electricity required	No	No	Yes< 20 amp single phase	Yes< 20 amp single phase	Yes, 50-100 amp 3 phase	Yes, 50-100 amp 3 phase	Yes, 200 amp 3 phase	Yes, 200 amp 3 phase
Capital requirements	\$10	\$15		5500				\$85,000 equip. but no marketing, materials or storage
Non monetary benefits		Avoids purchased energy and foreign exchange deficits. Provides employment for many people with no access to capital/machinery.						Prestige in training of personnel in high skill level

Data for artisanal products courtesy Bill Smith, Mastercraftsman, Lynden, Washington, and for International quality furniture courtesy of Steve Ulrich, co-owner, Wildlife Collection, Kingsville, TX, USA

### **Technology to produce value added human food products.**

The equipment used to produce value added human food products is basically the same as listed in Section VI Development of human and animal food uses of *Prosopis* pods. One of the most important differences between the human and animal feed flour is the fine grinding of the mesocarp flour to a minimum of 80 mesh. The 20 and 40-mesh flour have the appearance of a coarse, non-refined flour due to non-homogenous particle sizes, perhaps due to small portions of the pod pericarp. Thus a second mill with closer tolerance grinding mechanism is necessary to produce a more homogenous finer ground flour that is both more visually appealing and that is softer to the touch. This finely ground flour can be used as the starting material for many food products.

### **VIII Increase quality of food and wood products commensurate with international government and marketplace standards.**

For *Prosopis* human food products, it will be necessary to develop sanitation quality standards something analogous to US Food and Drug Administration *Food Defect Action Level* (FDAL) (levels represent the limit at or above which FDA will take legal action against the product to remove it from the market) for contaminants such as insect eggs, larvae and parts, bacteria, mould, mycotoxins or filth in *Prosopis* food products. (For example insect filth for cacao flour is an average is 60 or more microscopic insect fragments per 100 grams). Additionally it will be important to develop a Hazard Analysis Critical Control Point (HACCP) system as outlined in the FAO Bulletin "Quality Assurance for small-scale rural food industries" [www.fao.org/docrep/V5380E/V5380E06.htm](http://www.fao.org/docrep/V5380E/V5380E06.htm) to control quality from sources of contamination by micro-organisms, biological, chemical or physical contaminants

With very few exceptions, most furniture produced in Ethiopia does not have the design style, joinery or finishing to be marketed acceptably in Europe or the United States. For furniture it will be first important to provide furniture made from lumber dried to about 12 % by either kilns or prolonged air-drying. The sanding (to > 220 grit), joinery, and finishing will all have to be substantially upgraded. The rudimentary designs and dark stains will have to be modified to accommodate European and North American tastes. It would be highly desirable to obtain foreign input on the furniture design and construction. In the United States it would be useful to seek assistance from associations such as the American Society of Interior Design (ASID), the International Business Designers (IBD), the American Institute of Architects (AIA) to improve construction and design. In Europe research institutes such as the Technical Centre for Wood and Furniture (CTBA) in Paris, France ([www.ctba.fr](http://www.ctba.fr)) or the Institute for Wood Research (IRL) in Florence, Italy (<http://www.area.fi.cnr.it/irl/irl.htm>)

### **IX Develop national and international markets for improved products.**

It is envisioned that the development of *Prosopis* based industries must be driven by market demand from the private sector. Further it is envisioned that public funds will not be used for subsidies for plantings but rather through an iterative process of cost and market analysis and applied research to resolve critical needs necessary to develop "bankable projects" which merit private investments. However it is

envisioned that public funds will be required to fund new product development and introduction of these products to the national and international marketplace

While inexpensive systems to keep people alive, put more food on the table and make more firewood available cannot be abandoned, it is mandatory to find a permanent solution to the destitute socio-environmental conditions in Ethiopia's arid lands where *Prosopis* exists. Even the poorest regions in the poorest countries in the *Prosopis* network can benefit from a market analysis of locally available *Prosopis* products, or new redesigned products with greater market acceptance.

### **Development of markets for human food uses of *Prosopis*.**

Human food products derived from *Prosopis* pods would seem to have two general basic classes of use, (1) for taste and aroma enhancement at low concentrations (12-20% range), rather than structural property enhancement in wheat and maize based products for the normal population and (2) in gluten free products for celiacs where the flour concentration may be as high as 50%.

*Prosopis* flour is an interesting product in celiac applications since the protein content of *Prosopis* mesocarp flour of 8.1% is slightly higher than rice flour (6.7% protein-FAO, 1972) and considerably higher than manioc flour (1.6% protein FAO, 1972). The local chapter of Celiacs in Santiago del Estero, Argentina is currently using 50 % *Prosopis alba* flour, 25 % rice flour, 25% manioc flour, other minor ingredients and 1% guar gum to increase the mixing properties of the flour. Thus an important marketing strategy would be to develop recipes for the celiac community that are both more functional structurally and that have better consumer acceptance. Publication of these recipes and the availability of this flour in publications and web sites devoted to gluten intolerance would be an important marketing objective.

The sensorial analyses of incorporation of *Prosopis* flour into maize tortilla chips (Ph.D. thesis of Meyer (1984) found that at *Prosopis* flour concentrations of 10 and 20% a much more favorable response was obtained with the *Prosopis* flour. Thus it would seem reasonable to produce maize tortilla chips (which do not have volume problems like incorporation into wheat-based bread) and to send samples of these tortilla chips to major tortilla chip manufacturers. An Ethiopian modification of this recipe would be to include *Prosopis* flour into the flat "tortilla type product" made from the local indigenous cereal teff.

There are many web sites that deal with bread and pastry manufacture [www.panader.com](http://www.panader.com) (In Spanish) where it would probably be easy to introduce information about *Prosopis* flour and to offer samples at cost. Many of these bakery associations have annual conventions where distributors of bakery products have exhibitions. These conventions should be attended and flour samples and fact sheets provided to the wholesale distributors of bakery products. If only one or two of these companies would consider distributing *Prosopis* flour, great advancements in market penetration could be achieved.

Culinary schools are often associated with international hotel management and are composed of young students eager to try new indigenous products. It will be

important to identify these schools, make contact and supply limited flour samples for them to experiment.

### **Development of markets for lumber, furniture and wood products.**

The world markets for lumber, flooring, architectural wood products and furniture are very well organized and with minimal resources it should be possible to sell value added *Prosopis* wood products in the national and international market place.

Due to Ethiopia's long relationship with Italy and very strong Italian furniture industry, efforts should be made to introduce *Prosopis* lumber to the Italian furniture industry. While there is little wood technology data specifically on *P. juliflora*, all of the well characterized species in section Algarobia of the genera *Prosopis* i.e. *P. glandulosa* var. *glandulosa*, *P. velutina*, *P. alba* and *P. pallida* have superb dimensional stability and there is little reason to believe that *P. juliflora* from Ethiopia would be significantly different. One of Italy's largest furniture manufacturers, Berloni has very successfully used *Prosopis* lumber from Argentina and in all probability would have interest in purchasing *Prosopis* lumber from Ethiopia. Dr. Nicola Macchioni of the Wood Research Institute (IRL) at Florencia, Italy has collaborated on a European Union proposal to produce panels from *Prosopis* using small diameter short logs and would probably be interested in collaborating with the Ethiopian Forest Industry if funds were available to finance to adapt technology to produce furniture grade panels from *Prosopis* from small diameter, short logs.

Almost every country has a yearly national exhibition of furniture and/or lumber products. The most inexpensive approach would be to visit all the booths in one of these exhibitions to distribute technical information and explain the wood properties of *Prosopis*. A more expensive approach would be to purchase space for a small booth (3-m by 3m) and to demonstrate various *Prosopis* wood products. For an international exhibition a 10 square meter booth normally has a charge of about \$2000.

Most countries also have associations of architects and interior designers that have professional magazines that are published quarterly and it is often very easy to have a technical article on emerging uses of *Prosopis* wood published (as opposed to articles describing a particular new company's products). Some international journals such as the Tropical Timber Journal, are willing to share in the costs of sending one of their journalists to write an article (with photographs) of innovative forestry themes.

The commercial hardwood lumber and flooring industry has printed an electronic means of selling their products. For example the Hardwood Market Report, ([www.hmr.com](http://www.hmr.com)) which is a weekly report in the USA of trends in lumber prices, has advertisements of the major hardwood lumber buyers in the US. For about \$2000 per year a cooperative of wood producers (or a government sponsor) could place advertisements in these journals that could be replied to in electronic fashion. Similarly the National Wood Flooring Association has a web site ([www.woodfloors.org](http://www.woodfloors.org)) and a very large annual exhibition where *Prosopis* flooring could be sold. It is also possible to buy and sell wood flooring via the internet at [www.woodfloorsonline.com](http://www.woodfloorsonline.com)

In summary there are a myriad of local, national and international exhibitions, trade journals, and web sites where value added *Prosopis* products can be marketed. The examples cited above are only meant to be illustrative of the potential possibilities.

## **X Economic Analyses**

### **Introduction**

The kind of substitution analyses that FAO supported for cassava in which it was found that a 10% substitution of wheat flour by cassava flour would result in at least an increase of 20% demand of cassava in 23 countries (Global Cassava Market Study: Business opportunities for the use of cassava, 2000) is also appropriate for analyzing the potential impact of the *Prosopis* lumber and human food market.

For the wood market it will be necessary to determine (1) the imported hardwood lumber volumes and price (as opposed to pulp & paper and construction timbers), (2) the size of furniture manufacturing industry in the country both in terms of gross value and number of employees. This data also needs to be developed on a regional level. From this data it will be possible to determine what kinds of impacts substitution by plantings financed by medium and large-scale investors would provide.

This same kind of analysis will be important in the development of human food uses of *Prosopis* pod products by analyzing the effect of substitution of various percentages of wheat flour with *Prosopis* flour in the production of specialty sweet pastries (as opposed to just inexpensive bread) and in the emerging markets for the gluten intolerance community.

### **Potential of *Prosopis* in the solid wood industry**

In analyzing the potential of the *Prosopis* solid wood industry in, it is important to take into consideration existing analyses and national plans for the forestry sector as a whole. The Ethiopian Forestry Action Plan (EFAP, 1993) of 1993, which was a highly participatory action plan supported by UNEP, FAO, the World Bank, GTZ, SIDA provides an extremely comprehensive analyses and overall recommendations for forestry initiatives in Ethiopia. It is pertinent to briefly review some of the highlights from this Forestry Action Plan.

Table 4 from that plan dramatically shows the overwhelming importance of fuelwood in the Ethiopian economy and that the estimated demand is 3.5 times the sustainable supply. This high fuelwood requirement is consistent with the fact that it has been estimated that woody biomass provides about 75% of Ethiopia's total energy requirements. In a comparison of wood energy in Ethiopia to Rwanda, Mali, Kenya and Zambia shows Ethiopia relies much more heavily on woody biomass for energy than the other countries

Table 4. Current sustained yield and demand for various forestry wood products in Ethiopia.

	Million cubic meters	
	Sustained yield	Demand
Industrial wood	0.2	0.4
Construction wood	1.1	2.1
Fuelwood	12.5	44.9
All	13.8	47.4

As can be shown in Table 5 of all the land types that support woody vegetation the bushlands and shrublands comprise by far the greatest surface area.

Table 5. Surface areas, growth stock and incremental yields of major vegetation types in Ethiopia in 1992 (FAO)

Forest Resource	Area Million ha	Growth stock cubic m/ha	Annual increment yields	
			Per unit area cubic meters/ha/yr.	Total Million cubic meters
Natural high forest	2.3			0.3
Slightly disturbed	0.7	90-120	5-7	
Heavily disturbed	1.6	30-100	3-4	
Woodland	5.0	10-50	1.2	6.4
Bushland	20.0	5-30	0.2	4.0
Plantations	0.2		9.6-14.4	1.6
Farm Forestry				2.1

Source EFAP Final report table 2.2.1

Thus it can be seen that of the total annual incremental yield of approximately 12.5 million cubic meters of wood, 10.0 million cubic meters or 80% is derived from the bushland or woodlands and this small diameter wood is useful for fuelwood.

The 1997 FAO wood consumption statistics for Ethiopia in Table 6 illustrate that industrial roundwood consumption is only 5% of total wood consumption and that as confirmed above, fuelwood and charcoal consumption account for 95% of total wood consumption. With regard to industrial wood production and consumption, due to continued exploitation for fuelwood, Ethiopia is one of the lowest in the world, with similarly sized Tanzania producing 5 times the sawnwood. Ethiopia's sawnwood consumption of only 35,000 cubic meters per year is a very low quantity and if valued at prices of \$400 per cubic meter represents a national sawnwood industry of only about \$14 million per year. As discussed later in comparison to the European community yearly furniture total sales of 62,000 million euros, this quantity is incredibly small.

Table 6. Wood consumption statistics for Ethiopia in 1997.

<b>Consumption Statistics - Ethiopia</b>			
<b>Consumption - roundwood</b>	<b>000 m<sup>3</sup></b>	<b>000 board feet</b>	<b>% of total</b>
Fuel and charcoal	49,827	10,199,587	95
Industrial roundwood	2,483	508,270	5
Total roundwood	52,310	10,707,857	100
<b>Consumption - sawnwood</b>			
Sawnwood	35	14,830	73
Panels	13	5,508	27
Total sawnwood	48	20,338	100
<b>Consumption - paper</b>	<b>000 metric tons</b>	<b>000 tons</b>	<b>% of total</b>
Paper and paperboard	15	17	88
Recovered paper	2	2	12
Total paper	17	19	100
<b>Consumption - wood pulp</b>			
Total pulp	7	8	100

Data are 1997 trade data from [www.fao.org/fo](http://www.fao.org/fo)

The Ethiopian wood import statistics shown in Table 7 clearly show the virtually complete absence of any significant industry that could be connected with furniture or other high value solid wood application.

Table 7. FAO values for Ethiopian wood import statistics in 1997.

<b>Import Statistics - Ethiopia</b>			
<b>Wood</b>	<b>000 m<sup>3</sup></b>	<b>000 board feet</b>	<b>US\$ (mil.)</b>
Roundwood	0	0	0
Sawnwood and panels	3	1,271	0
<b>Pulp/paper</b>	<b>000 metric tons</b>	<b>000 tons</b>	<b>US\$ (mil.)</b>
Paper	7	8	5
Pulp	7	8	2
<b>Export Statistics - Ethiopia</b>			
<b>Wood</b>	<b>000 m<sup>3</sup></b>	<b>000 board feet</b>	<b>US\$ (mil.)</b>
Roundwood	0	0	0
Sawnwood and panels	0	0	0
<b>Pulp/paper</b>	<b>000 metric tons</b>	<b>000 tons</b>	<b>US\$ (mil.)</b>
Paper	0	0	0
Pulp	0	0	0

**Balance of trade US\$ (mil.) -7**

Data are 1997 trade data from [www.fao.org/fo](http://www.fao.org/fo)

Ethiopia has plantations of Eucalyptus, Cupressus lustanica and Pinus patula which constitute about 69%, 29% and 2% of the total planted areas (Kindu, 2001). The eucalyptus plantations are used for energy while the cypress and pines are used in the construction of furniture. However neither of the latter woods are suitable for high quality furniture. The report by Kindu, (2001) states that while Cupressus wood is soft



and easily worked, it is not a stable wood and has defects with regard to warpage, bending, twisting and surface checks. Similarly Kindu (2001) stated that the Pinus wood was too soft for high-class furniture but could be used for light box and crate manufacture, shingles, cheap joinery etc. For these reasons imported lumber imported from Austria, Kenya and Sweden was preferred for furniture manufacture even though the prices were much greater, sometimes as much as \$620 per cubic meter for Swedish lumber vs average prices of \$265 per cubic meter for Cupressus and \$277 per cubic meter for Pinus patula (at conversion rate of 7 birr/US dollar).

At this juncture it is important to point out that from a furniture and flooring perspective, *Prosopis* wood is not only far superior to Cupressus and Pinus patula but is on a par with the world's very finest cabinet woods. For example a comparison of the wood technical properties of *P. pallida* (from Peru) to 7 of the most important commercial species from the rainforest side of Peru in Table 8.

None of these 7 Peruvian species has as low a total volumetric shrinkage of *Prosopis* and none of them have as low a ratio of tangential to radial shrinkage. This latter coefficient is important since woods with similar tangential and radial shrinkage, shrink equally in perpendicular directions and thus in the drying process there is less warping, twisting etc. This characteristic is important in fine furniture manufacture as drawers, doors and joints since wood with lower shrinkage (and a lower tangential to radial ratio) will have less tendency to expand and contract with changing seasons of the year or when furniture is moved from a high humidity environment to a low humidity environment. This characteristic is of great importance for exterior applications such as windows, window shutters and doors

In addition, *Prosopis* has adequate and above average values for break up module (bending strength), elasticity and parallel compression or resistance to crushing. The fact that algarrobo has greater side hardness, greater perpendicular compression and equal parallel compression indicates that *Prosopis* would have superior resistance to wear in flooring applications. This hardness, when combined with resistance to movement with regard to changing moisture environments would make *Prosopis* a truly superior parquet flooring material. Obviously given the predominance of short logs, this would be an excellent application for Ethiopian *Prosopis*.

**Table 8. Comparison of the physical mechanical properties of algarrobo to 7 of the 9 nine most important commercial species in Peru**

	Algarrobo <i>Prosopis pallida</i> (1)	Coaba <i>Swietenia macrophylla</i> (2)	Copaiba <i>Copaifera officinalis</i> (3)	Tornillo <i>Cedrelinga catenaeformis</i> (3)	Ishpingo <i>Amburana cearensis</i> (3)	Catahua <i>Hura crepitans</i> (3)	Cumala <i>Virola</i> sp(3)	Moena amarilla <i>Aniba</i> (3)
Density (g/cm <sup>3</sup> )	1.07	0.43	0.55	0.41	0.43	0.35	0.44	0.60
Shrinkage Volumetric	6.3	8.8	14.6	11.8	8.0	7.30	13.7	12.1
Shrinkage Tangential	3.61	5.54	9.2		4.95	4.50	8.8	7.0
Shrinkage Radial	2.51	3.17	4.4		2.65	2.70	4.6	4.7
Ratio tang/radial	1.44	1.70	2.09		1.83	1.66	1.91	1.48
Break up module (kg/cm <sup>2</sup> )	1058	524	1492	<b>535</b>	754	613	771	1340
Module of elasticity 10 <sup>3</sup> (kg/cm <sup>2</sup> )	132	94	186	<b>97</b>	96	82	144	180
Parallel compression (kg/cm <sup>2</sup> )	615	240	753	<b>254</b>	429	338	362	704
Side hardness (kg)	1442	298	790			250	290	668

Data from (1) Eduardo Loayza, (2) data from Paola Sanchez Takamura, (3) Tropical timbers of World (Chudnoff, 1984-USFS Agricultural Handbook No. 607-1984) using data for wood of 12% moisture where Bending strength break up module, and maximum crushing strength is parallel compression (14.2 Psi = 1 kg cm<sup>2</sup>). Data for dry wood not available and this data in **Bold** for (3) are for green wood.

A comparison of the physical/mechanical properties of *Prosopis pallida* to Ethiopia's plantation species Cupresses and *Pinus patula* in Table 9 shows the technical superiority of *Prosopis* to Ethiopia's current plantations species for furniture and flooring applications.

**Table 9. Comparison of the physical mechanical properties of *Prosopis pallida* to Ethiopia's commercial plantation furniture species.**

	<i>Prosopis Prosopis. pallida</i> (1)	Mexican Cypress <u>Cupressus</u> <u>lustranica</u>	Patula Pine <u>Pinus</u> <u>patula</u>
Density (g/cm <sup>3</sup> )	1.07	0.39	0.45
Shrinkage Volumetric (%)	6.3	8.0	12.6
Shrinkage Tangential (%)	3.61		7.9
Shrinkage Radial (%)	2.51		4.1
Ratio tang/radial	1.44		1.92
Break up module (kg/cm <sup>2</sup> )	1058	724	
Module of elasticity 10 <sup>3</sup> (kg/cm <sup>2</sup> )	132	72	98
Parallel compression (kg/cm <sup>2</sup> )	615	378	422
Side hardness (kg)	1442	209	

Data from (1) Eduardo Loayza, (2) Wood Handbook: Wood as an engineering material USDA/USFS handbook 72-1987, (3) Tropical timbers of World (Chudnoff, 1984-USFS Agricultural Handbook No. 607-1984) using data for wood of 12% moisture where Bending strength break up module, and maximum crushing strength is parallel compression (14.2 Psi= 1 kg cm<sup>2</sup>).

The only drawbacks to the use of *Prosopis* for fine furniture are the much shorter clear lengths of logs, and the fact that *Prosopis* is more difficult to work due to greater hardness. However the proliferation of sawmill equipment especially designed for

small logs, the increased availability of new high speed steels, carbide, diamond and stellite tipped saw blades used for hard woods, and finger jointing and edge glued panels that effectively use short lengths, all serve to overcome the length/hardness issues of *Prosopis*. In contrast, there is little that can be done about an inherently dimensionally unstable wood.

It is important to highlight the potential of edge glued panels from *Prosopis*. In many applications such as kitchen cabinet doors, sides of desks, doors, etc, it is common for furniture manufacturers to purchase panels of standard lengths and widths that are made of small boards that have been glued together. With today's glues these standard sized panels are of excellent quality and provide considerable savings in labor to furniture manufacturers. As the production of these panels is labor intensive they are difficult to produce economically in technically advanced companies. However, with Ethiopia's abundance of inexpensive labor, this would not be a problem. It is strongly suggested that production and evaluation of pilot scale quantities of *Prosopis* edge glued panels be made.

Given these outstanding characters, in the economic analysis of competing uses and economic potential, it seems reasonable to assume a value for *Prosopis* of \$ 2 per board ft or \$856 per cubic meter for lumber and \$20 per square meter for 14 mm thick flooring for \$1430 per cubic meter of flooring. These prices are greater than those listed in the Hardwood Market Report ([www.hmr.com](http://www.hmr.com)) for common species such as oak (*Quercus*), equal to intermediate value woods such as walnut (*Juglans nigra*) (which has much lower dimensional stability) but less valuable than exotic imported woods such as mahogany. The prices are also similar to World Bank benchmark prices of Malaysian sawnwood of \$740 per cubic meter. ([www.worldbank.org/html/ieccp](http://www.worldbank.org/html/ieccp)).

The estimates of annual growth assume managed stands in which 1.2 cm diameter growth per year is achieved for a stand of 100 trees/ha (10 m by 10 m spacing) and using all wood down to smallest domestic parquet size of 8mm by 6 mm by 240 mm. This results in an annual increment of 0.5 cubic meter of sawn lumber per year (Felker, 2001). It is to be noted that the mean diameter growth of 1800 *Prosopis pallida* trees on the University of Piura, Peru experiment station was 1.1 cm per year on a 10 by 5 m spacing and that all the superior cloned trees had an annual diameter increment greater than 2 cm.

**Table10. Economic impact of management of *Prosopis* dry forests for lumber production with *Prosopis* lumber valued at \$856 per cubic meter with annual sawn lumber production under management of 0.5 cubic meters per year.**

Scenario	Area under sustained management (ha)	Percentage of Ethiopian Bushland under management (%)	Sawn lumber production per year. Cubic meters	Value of lumber per year (millions \$US)
1	5000	0.0125	2500	2.1
2	25000	0.0625	12500	10.7
3	50000	0.1250	25000	21

It is significant that the EFAP (1993) recognized the need for value-added wood processing enterprises and budgeted \$15 million for the rehabilitation of production facilities for sawmills, and veneer, plywood, panel board and joinery industries. Such an effort would also be highly appropriate to development of portable, small-log-sawmill systems to produce furniture components and edge glued panels from *Prosopis*.

Thus there is every reason to believe that a serious sustainable management program for Ethiopia's existing *Prosopis* forests could sustain a combined lumber, furniture and flooring industry with annual revenues in the range of \$25 million.

With regard to potential for export, the European furniture market would seem to be a market with great potential given the increased urbanization in Europe leading to less forested areas and the ever increasing demand for furniture. According to "The State of the Competitiveness of the EU Forest-Based and Related Industries: "Communication from the Commission COM (1999) 457 Final - 5-10-1999.", the production value of the European furniture in 1998 was 68,598 Million Euro, with 19,409 enterprises that had 675,793 employees. The number of companies which are engaged in the manufacture of furniture is about 70,000 in Europe with lots of very small companies, about 60,000 with less than 20 employees, in particular in Italy, Spain and United Kingdom. But it is of significance that around 70% of the overall sales of the European furniture industry is accounted for by 1,500 companies with 100 or more employees. Further, according to UEA sources, the 1998 furniture production of the European Union (15 countries) was 62 billion Euros (the first producer is Germany, the 2nd Italy, the third France).

### **Economic analyses of potential for human food uses.**

A comparative economic analyses of the production of *Prosopis* flour production in Peru and Argentina for human uses was recently submitted for publication (Felker et al., 2002). As opposed to other analyses which only included processing costs delivered to the plant, this analysis ascribed a \$30 per ton value to the owner of the trees (separate from collection costs) in order to provide incentives to plant and care for the trees. The sensitivity analyses showed that the two most economically important factors were the conversion efficiency of pods into flour and the labor rate. When a 40% conversion efficiency, such has been obtained in both Peru and Argentina was obtained, and by-product credits for high fiber containing fraction were assumed, the wholesale selling price with a 5 % marketing cost and a 40% profit on direct costs was estimated to be \$0.66 kg<sup>-1</sup> for Peru (using a \$0.40 hr<sup>-1</sup> labor rate) and \$1.76 kg<sup>-1</sup> for Argentina (using a \$1.5 hr<sup>-1</sup> labor rate).

These authors felt that due to the considerably higher cost of *Prosopis* flour than wheat or maize flour, *Prosopis* flour will achieve its greatest economic value resulting from its cafe/cacao/cinnamon/mocha aroma and taste, rather than any benefit from textural properties. As this flour does not contain gluten, the other major market would be the market for celiac food products.

An immediate opportunity for the use of *Prosopis* flour would be through the national government programs that distribute food to the poor. If *Prosopis* flour were included in current flours at a 15% concentration to enhance the flavor and aroma this would constitute a very significant national market for *Prosopis* flour and provide a great stimulus to invest in collection, drying and milling machinery to produce the flour.

It has not been possible to obtain the consumption of wheat flour used for the sweet pastry market or the size of the celiac specialty food market. However in a country with 60 million people, and 2.3 million in Addis Ababa, even with a small percentage consumption of *Prosopis* flour in sweet pastries or in food for celiacs, the potential market is great. It would be possible to determine the consumption of sweet pastry type products from flour sales of the major bakery distributors and/or by sampling a percentage of the bakeries. Once the per capita consumption of sweet pastry products and the per capita consumption of celiac products were known it would be possible to calculate potential sales of *Prosopis* flour products assuming various substitutions of these markets.

## **XI Attraction of private sector investments**

### **A. The human food industry**

The most likely candidate for investors in the human food industry would appear to be large landowners or village communities who have thousands of *Prosopis* trees. It would be of obvious and immediate benefit for them to install simple machinery to wash, dry, mill and sieve the flour. They would need to invest in a marketing initiative to contact local bakeries to develop a product line with *Prosopis* and to invest in marketing flour to the gluten intolerance community (celiacs).

Another possible source of investments would be associations of celiacs who need to have other sources for their bakery products. In this regard *Prosopis* flour is slightly higher in protein than rice flour and several fold higher in protein than manioc flour.

Until a strong demand is created for *Prosopis* flour for any human food application, it seems unlikely that milling or food companies will be interested in investing in these types of applications. Thus it seems imperative to work on new product development, including sensorial analyses of new products to create a demand that will in turn generate private investments.

### **B. The lumber/furniture industry.**

The sustainable development of any industry must place reliance on development of private sector that is willing to invest in its future. Given the excellent technical characteristics of *Prosopis* wood and new technologies to process and utilize small lumber sizes, it would appear that a *Prosopis* hardwood lumber and flooring industry should be possible in Ethiopia. The problems at present are: (1) the technical characteristics of for fine lumber are unknown in Ethiopia and potential export markets in Europe, (2) there is no current Ethiopian experience in the utilization of *Prosopis* for furniture or flooring and (3) the financial resources of the private sector of the Ethiopian Forestry industry are very limited thus impairing the medium term development of this new lumber/flooring/furniture industry.

Ethiopia has traditionally received considerable international donor support for economic development activities and it is suggested that these types of funds be used to stimulate the development of high value lumber/furniture industries in the arid lands. However, it is this authors opinion that these funds should be used to develop European high value markets and then when orders for production have been obtained, to provide loans to the private sector and not to subsidize sawmill/furniture modernization. Specifically international donor funds should be sought to: (1) contract with the Centre Technique du Bois et de l'Ameublement (CTBA)([www.ctba.fr](http://www.ctba.fr)) in Paris, France to produce *Prosopis* furniture according to European styles and to test market this furniture in European furniture fairs, (2) to contract with Istituto per la Ricerca sul Legno (IRL= Wood Technology Institute) in Florence, Italy who has experience in producing edge glued panels from short, small diameter Robina logs to produce small quantities of *Prosopis* edge-glued-panels for use as marketing samples(and corresponding technical data on the panels), (3) to contact specific hardwood lumber purchasing companies such as Berloni in Italy and Theodor Nagel Gmbh & Co. in Hamburg, Germany to seek orders for lumber and edge glued panels and (4) to provide financing to contract for booth space, sample preparation and promotional literature in major European hardwood lumber, flooring and furniture fairs.

Once firm orders for pilot scale samples or commercial samples have been received, it would then be reasonable for the international donors to provide attractive financing to private sector firms to provide working capital and to modernize equipment to fill the orders.

Domestically, a campaign is needed to increase the awareness of the private sector of the qualities of *Prosopis* and the moderately attractive internal rate of return that can be achieved from investments into the wood industry. The limited technical data available on the wood is similar enough to *Prosopis* data from the US and Argentina to indicate that it too is a very dimensionally stable wood. Annual diameter growth rates for *Prosopis* in Peru (which is very similar species to that in Ethiopia) are greater than those assumed for an Argentine investment brochure in which a 9.3% rate of internal return was calculated without taking into account revenues that might be generated from intercropping, pod production or carbon sequestration (Felker, P. 2000. An investment based approach to *Prosopis* agroforestry in arid lands. *Annals of Arid Zone* 38: 383-395 or ([http: Prosopis.url4life.com](http://Prosopis.url4life.com)). While this 9.3% is somewhat low, it still is a reasonably attractive investment for the forestry sector given the lack of foreseeable supplies of high quality lumber in the next 25 years when this lumber would be available. The availability of more productive clones with shorter rotation cycles should greatly increase the attractiveness of these commercial plantations. It is suggested that an investment brochure similar to the one developed for *Prosopis* in Argentina ([http: Prosopis.url4life.com](http://Prosopis.url4life.com)) be developed for Peruvian *Prosopis* to be used in a campaign to attract investors.

To attract both the medium and large scale investor, it will be necessary to produce the feasibility analyses, identify the risks for potential markets, and determine the cash flows required for the plantations in these difficult areas. This will benefit the local people by providing jobs in tree nurseries, driving trucks, weeding, pruning and many other support activities.

All size classes of investors are possible from small landowners to foreign international banking/investment firms. Poor farmers with only a hectare may be interested in planting a few trees for immediate multiple uses as well as a long term investment for his retirement or his children. Small rural villages invariably have a few visionary owners of 5 to 10 ha who have strong positive feelings for *Prosopis* and the environment and with provision of improved multi purpose trees would be interested in committing portions of fields, field boundaries or long term intercropping farming systems to production of *Prosopis*. Cities, both large and small, usually have environmentally sensitive businessmen such as doctors and lawyers who own rural properties and would be interested in long term *Prosopis* investments.

It would seem appropriate for a consortium of universities and government agencies seek funding to develop the feasibility studies and make the national and international contacts for *Prosopis* projects in Ethiopia. At this time the proposal should probably be for small-scale projects to verify the annual production and economics. Given the long-term interests in forestry companies it would be appropriate to involve them from the start in small-scale verification projects.

**XII Use in environmental amelioration, reclamation of saline/high pH soils, control of sand dune movement, increase in soil N carbon and ensuing C sequestration.**

The arid northern regions of Ethiopia where *Prosopis* is adapted, has a considerable number of severely degraded ecosystems where the production of useful products will probably not be high enough to justify reforestation from the private sector, but which nevertheless are in urgent need of reforestation for environmental amelioration. It is not known whether maps exist to classify the extent of these degraded areas. If such maps exist they should be overlain with the surfaces that are possible for reforestation with *Prosopis* and the priorities for such reforestation.

Recent hydroponic trials examining the salt tolerance of Peruvian *Prosopis*, found that virtually all these *Prosopis* grew well at salinities up to 20 mmhos, grew moderately well between 20 and 35 mmhos and that some strains and individual seedlings still grew at 45 mmhos which is the same salinity as seawater (Most annual crops tolerate salinity of 3-4 mmhos with significant yield losses). It is highly likely that significant proportions of the saline areas have salinities of 45 mmhos or less, but it is also highly probable that some areas have salinities from 80 to 150 mmhos which would be an impossible condition for growth of even the most salt tolerant *Prosopis*. It would be useful to attempt reforestation *Prosopis* reforestation trials in several areas representative of the 10- 20, 20 to 30 and 30 to 40 mmhos salinity regions.

International funds should be sought to (1) map these degraded areas according to slope, soil texture (primarily to distinguish sand dunes from rocky hillsides) and broad salinity classes (10-20, 20-30, 30-40, 40-50 and >50mmhos), (2) prioritize the need for reforestation, taking into account the current technology available and (3) to initiate pilot scale demonstration/research plots on representative areas.



### **XIII Ecological certification**

Ecological certification is a seal of approval backed by the Forestry Stewardship Council (FSC) to guarantee that the products of the forest are produced in a manner that is sustainable and that takes into consideration the needs of the people who may be accessing the forest, for example for food byproducts and medicinal plants.

Without Ecological certification, many European markets will be closed to lumber products due to the very strong consumer movement that will not purchase products without assurance that the neither the forest or the people who live in or near the forest are being exploited. Approval for ecological certification, sometimes known as the Green seal, requires development of a management plan and a visit by a multidisciplinary team, usually consisting of a forester, a sociologist/anthropologist and a financial analyst. In addition to certification of the products from the forest, ecological certification also requires that the certified products be tracked from the forest to the final point of sale by a "Chain of Custody" to ensure that non-certified products are not being mixed and sold as being certified. One organization that has worked extensively in Latin America to develop ecological certification is SMARTWOOD [www.smartwood.org](http://www.smartwood.org). This organization has provided an estimate of about \$10,000 to certify 4000 ha of forests in Argentina and it has been stated that certification can be obtained in about 4 months if no major local problems exist. In addition to certification organizations such as Smartwood provide extensive lists of many companies interested in purchasing certified wood.

It is suggested that Ethiopia seek international donors to provide funding to initiate at least a small certification program for about \$15,000 and 6000 ha of native *Prosopis* forest.

### **XIV Increase production of the *Prosopis* resource base for wood (lumber, firewood charcoal), pods for human and livestock needs and environmental stability.**

To ensure the sustainability of the production for markets that are being generated, it will be important to also increase the production capacity for all *Prosopis* products from the following four resource bases.

In plantations without irrigation possibilities where ground water is within several meters of the surface.

In plantations without irrigation possibilities where no ground water is present but where the rainfall is greater than 550 mm per year.

In plantations with irrigation where rainfall < 550 mm/year

By managing existing stands with thinning, pruning, fertilization, grafting onto coppiced rootstocks of harvested trees

In environmentally degraded areas such as saline areas or abandoned irrigation lands

Stimulation of the production from the *Prosopis* resources base would best be accomplished by a mixture of private and public funding. Attraction of small, medium and large private investments into *Prosopis* production, as outlined in section XI will be useful in stimulating tree plantings at the household, village and regional levels. Owners of large tracts of existing stands should be contacted and explained the low levels of investment and high returns to be achieved from implementing a combined

management/marketing program for native stands that includes thinning, pruning and grafting resprouts of harvested trees with superior genetic materials.

National subsidies for tree plantations, such as exists in Argentina have been a great stimulus to development of the *Prosopis* plantations. This plan provides about \$400 per ha for plantings up to 300 ha. Thirty percent of the total amount is provided in the form of a bank loan prior to planting and the balance of the funds one year after planting if a supervising forester certifies the plantation has been adequately established and cared for. In the Province of Santiago del Estero in 2001, about 3000 ha of *Prosopis* plantations were approved under this system.

## **XV Possible participants in an integrated Ethiopian Plan for Prosopis.**

### **Institutions to be participants in the National Plan**

- IAR( leader)
- NGOs (.)
- Ethiopian wood companies
- National Committee for the Standardization of Prosopis Products
- Producers of Prosopis food products
- Associations of Celiacs

### **Possible cooperation entities**

- FAO
- Canada (CIDA / IDRC)
- EU (INCO-DEV / Tropical Forests / NGOs)
- Proyecto Algarrobo –
- GEF (PPD / PFD / MSP)
- GTZ
- USAID
- Swiss Agency for Development and Cooperation
- Embassies: Finland, Netherlands

## **XVI Summary**

An integrated *Prosopis* program has great potential to produce pods to increase human food security and livestock feed, to reduce the areas where it is a weed via control through utilization programs, and to provide a new forest industry with domestic and international markets based on the high quality *Prosopis* lumber.

For the development of *Prosopis* for human food applications it will be necessary to develop an infrastructure with mobile hammermills and portable solar dryers that can be transported in standard pick up trucks. This will provide the initial processing, stabilize the insect infestation and reduce the volume to be able to be transported to other locations for secondary processing. Markets need to be developed for the flour by contacting the international aid agencies to consider including *Prosopis* flour as a high energy/flavoring complement to traditional wheat and barley flours distribute to poor people in relief efforts. The celiac community needs to be contacted and provided with recipes using *Prosopis* flour. Samples also need to be provided to the bakeries in Ethiopia for inclusion at about 15% concentrations in traditional sweet

type pastries. As the Peruvian *Prosopis* has a reputation for being sweeter than the *P. juliflora* flour, it would be important to contract with the University of Piura to provide several hundred kg of the Peruvian *Prosopis* flour for comparative taste tests with the naturalized *P. juliflora* flour. If the Peruvian flour is preferred this would be an additional reason to consider importing the new elite Peruvian clones. Applied R&D is needed on sanitary processing systems to bring flour to international standards so it could be marketed internationally.

The 7 elite *P. pallida* clones identified in Peruvian trials with erect form, fast growth and high production of sweet pods needs to be imported to Ethiopia, tested in field trials and proven efficient clonal propagation and seed propagation methods installed.

The extensive weedy *Prosopis* stands in Ethiopia need to be approached in a control through utilization program. Since 75% of energy in Ethiopia is used for fuelwood and since > 95% of wood is used for fuelwood, there is great opportunity to both provide fuelwood and to control the weedy nature of *Prosopis*.

At the same time, it is important to recognize that *Prosopis* lumber is vastly superior technically to the existing plantation lumber species Mexican cypress and patula pine for high quality furniture and flooring. Thus *Prosopis* can provide a new dimension in the Ethiopian forestry industry by providing excellent raw material for high value lumber, flooring and moldings. In spite of the much shorter lengths and the much harder wood of *Prosopis*, with new short log sawmills and alloys with harder teeth these technical problems are easily overcome. To concentrate the growth on fewer "pruned crop trees" natural stand management and weed control efforts, will by necessity, need to work very closely together. Portable sawmills capable of converting low value small logs (20 cm diameter and 40 cm long) worth less than \$80 per ton to furniture parts, flooring worth \$1000 per ton need to be purchased and demonstrated. Training programs need to be instituted to produce high value added artisanal products from *Prosopis* and place these products for sale on the web.

International donors need to be contacted to assist in development of international markets for solid wood *Prosopis* products. Leading European wood technology institutes such as the CTBA in France and the IRL in Italy need to be contracted to produce *Prosopis* furniture and edge-glued panels respectively to serve as models/samples in international furniture/flooring conventions. Economic analyses indicate that for every 5000 ha or 0.0125 % of Ethiopia's bushland that is brought into sustained *Prosopis* management an additional \$ 2.1 million per year in lumber income will result.

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