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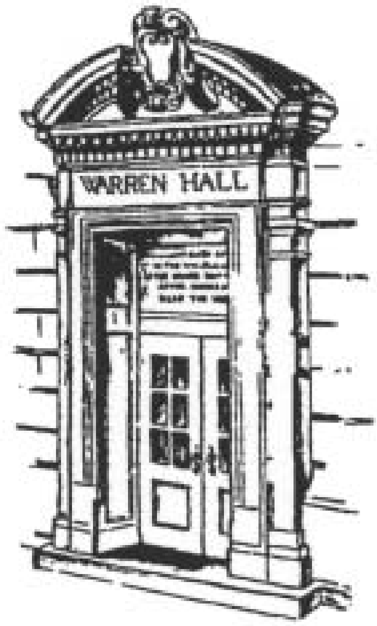

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Does Resource Commercialization Induce Local Conservation? A Cautionary Tale from Southwestern Morocco.

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Abstract:

Ecotourism, bioprospecting and non-timber product marketing have been promoted recently as market-based instruments for environmental protection, but without sound understanding of the resulting net conservation effects. We present evidence on the local effects of recent argan oil commercialization in Morocco, a seemingly promising case of conservation through resource commercialization. We find that resource commercialization creates mixed net conservation incentives because assumptions implicit in the prevailing logic prove incorrect. The experience of southwestern Morocco provides a cautionary tale about conservation strategies founded on resource commercialization, emphasizing that the biology of a resource often exerts greater influence on conservation outcomes than do market forces.

Running Title: “Does Commercialization Induce Local Conservation?”

Keywords: Conservation; Resource Commercialization; Bioprospecting; Non-timber forest products; Argan

I. Introduction

The past decade has witnessed widespread experimentation with market-based instruments for environment protection, including industrial emissions trading and transferable quotas in fisheries in wealthy countries, and the promotion of ecotourism, bioprospecting, game cropping and non-timber forest product marketing in poorer countries. Although such efforts appear to work well in some settings, a sufficient mass of empirical evidence does not yet exist to permit clear determination of the efficacy of such methods in achieving conservation objectives.

This is perhaps especially true with respect to tropical forests. Ever since Peters et al. (1989) claimed that a tract of rainforest could, under certain conditions, be more valuable if sustainably harvested than if logged or converted to pasture, environmentalists have eagerly embraced resource commercialization as a conservation strategy. Ecotourism, bioprospecting and the marketing of non-timber products have thus been aggressively promoted in recent years, but without a sound understanding of the actual net conservation effects of such efforts. This paper makes a contribution toward filling that void.

We present evidence on the local conservation effects of recent argan oil commercialization efforts in Morocco. The argan oil case is in part a bioprospecting story. European chemists recently discovered that the oil from the nut of the argan tree endemic to the dry forests of southwest Morocco exhibits desirable properties for cosmetics sold commercially throughout Europe, Israel and around the world. A dramatic expansion of marketing and processing of argan oil, complete with induced institutional and technological change, has resulted (Lybbert, 2000). The argan case is also partly a story of non-timber forest product marketing. Argan oil commercialization requires ongoing *in situ* nut harvesting, because attempted introductions elsewhere in the world have achieved little success and synthetic substitutes have yet to be developed. The extraction of oil from argan nuts likewise occurs *in situ* since the low value to weight ratio makes exporting the nuts for extraction *ex situ* unprofitable.

On the surface, the argan oil story therefore seems promising as a case of conservation through resource commercialization. Relatively poor forest dwellers pose the principal immediate threat to the forest via livestock that heavily browse argan trees. Goats, for example, often climb into the canopy of argan trees to feed directly on argan fruit, damaging the tree in the process. Locals produce the oil from the tree's fruit and they hold well-established access rights to the forest, so they are well positioned to reap the rents resulting from any increase in the value of argan fruit. Such benefits should provide locals with clear incentives to conserve increasingly valuable forests.

We find however, that resource commercialization is not creating strong net conservation incentives. Indeed, the biology of the argan tree and the organization of markets for argan products together may cause oil commercialization to harm the argan forest in the long run. As we will show, the prevailing logic of conservation through resource commercialization fails because crucial implicit assumptions prove incorrect in the case of argan oil. The experience of southwestern Morocco thus provides a cautionary tale about the efficacy of conservation strategies founded on resource commercialization.

II. The Argan Forest

The argan tree (*Argania spinosa* (L) Skeels) is endemic to Morocco, where it covers 867,000 hectares (ha), second in coverage only to the cork oak tree. The argan tree is unique and ecologically valuable. It is the only species of the tropical family *Sapotaceae* remaining in the subtropical zone, and its deep roots are the most important stabilizing element in the arid ecosystem, providing the final barrier against the encroaching deserts (Morton and Voss, 1987, Mellado, 1989, M'Hirit et al., 1998). The argan forest lies primarily within the provinces of Agadir, Taroudant, Tiznit, and Essaouira, hereafter termed the Argan Forest Region (AFR).

Nearly half of the argan forest disappeared during the 20th century as it succumbed to demand for high quality charcoal and, more recently, to conversion to agricultural production of export crops such as tomatoes. As evidence of the latter, a change assessment from 1981-87 in two communes of the Province of Taroudant indicated a significant drop in vegetation cover, which is almost exclusively argan forest, on 43% of the land area (Bakkoury, 1999). Many organizations are now devoting considerable resources to conservation of the AFR, based largely on argan oil commercialization. The oil extracted from the argan tree's fruit exhibits notable cosmetic, medical and nutritive properties that have sparked rapidly growing demand for argan oil in non-traditional urban and overseas markets, on which more in section IV.

Tenurial arrangements in the AFR, composed of customary, legal and Qur'anic elements, reflect argan's importance in Berber society by giving preferential treatment to the collection of argan fruit over all other activities (DePonteves, 1989, De Ponteves et al., 1990). Ownership of an argan tree is separate from grazing rights to the land around the tree, which may be separate from ownership of the land on which the tree grows. These rights are further divorced from access to argan fruit and wood.

Clearly established rights dictate spatio-temporal forest use patterns. Spatially, the argan forest is unofficially divided[1] into large tracts assigned to villages. These village tracts are then subdivided into two usufruct categories: communal and quasi-private. On the communally-managed portion, called *azroug*, all rights are held communally by residents of the village to which the tract is assigned. Within the *azroug,* villagers exercise their usufructuary rights, with the exception of cultivation, on a year round basis. Not surprisingly, the *azroug* is typically quite degraded.

While there is considerable variation across villages, only a relatively small portion of the village's forest tract is typically designated as *azroug*. The remainder is subdivided into quasi-private *agdal* units held by individual villagers. Possession of an *agdal* grants an individual exclusive seasonal fruit harvest rights, whether in the tree or on the ground. *Agdal* rights transfer primarily by inheritance, often divided amongst heirs, so that the rights to a single argan tree are sometimes shared by multiple heirs. *Agdal* rights are marketable, but are rarely sold in practice.

Customary usufructure arrangements also divide the forest into two distinct periods. During the communal grazing period, roughly from mid-September to mid-May, AFR households communally exercise their usufructuary rights on both private holdings and the state forest tract assigned to their village, regardless of whether the land has been designated as *azroug* or *agdal*. Then, around mid-May or early June, regional appointed officials formally open the

[1] No official records exist that delimit precisely these demarcations, although local authorities are well aware of the traditional demarcation of each village's tract of forest land.

agdal season,[2] or fruit harvest, at which point harvest rights become exclusive within individuals' *agdals*. A household may exclude others from their *agdal* during the *agdal* season[3] by constructing a temporary enclosure around their assigned trees. Only the *azroug* remains open for communal grazing during the *agdal* season, during which a household must graze or browse their livestock either on their own *agdal* or on the *azroug*. The resulting seasonal crowding contributes significantly to forest degradation in the *azroug.* The temporal and spatial dimensions of the argan forest tenure system are characterized in Figure 1.

Today, the greatest threats to the argan forest arise from intensification of livestock browsing and grazing and the expansion of urban and rural settlements. Livestock numbers have increased substantially (Lybbert, 2000) and obvious signs of overgrazing and overbrowsing are everywhere in the argan forest. Browsing directly harms the existing, mature argan trees as goats will climb high into the branches of an argan tree to reach its fruit. During the off-*agdal* season livestock often still browse the leaves and branches of the tree. Large herds of camels also occasionally browse in the argan forest, leaving an easily identifiable trail of broken branches in their wake. Overgrazing can cause soil erosion, affects the microclimate of the forest by reducing ground cover and surface humidity and increasing temperature, and impedes the long term regeneration of the forest.

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[2] *Agdal* (literally, "forbidden") is used to refer to both the fruit-bearing season and to the physical cluster of trees for which usufructuary harvest rights are granted to a particular individual. For clarification, '*agdal* season' will refer hereafter to the fruit-bearing season while '*agdal*' will refer to the cluster of trees assigned to an individual.

[3] The length of the *agdal* season is determined by regional appointed officials, who also are responsible for resolving user conflicts in the forest, and varies according to level of precipitation and the resulting productivity of the forest. During extraordinarily dry years, which cause the tree to shed its foliage and temporarily curtail fruit production, the *agdal* season may be foregone altogether.

III. The Logic of Conservation Through Resource Commercialization

We turn now to the question at the core of this paper: does resource commercialization necessarily induce increased conservation? The logic of conservation through resource commercialization is clear. The net present value of conserving the underlying resource, π, is just the discounted stream of net benefits from harvest,

$$
\begin{aligned}
\pi(p, \{H_t\}_{t=0}^{\infty}, w, l) &= \sum_{t=0}^{\infty} \rho^t \left[pH_t - C(H_t, w, l) \right] \\
&= R(p, \{H_t\}_{t=0}^{\infty}) - \sum_{t=0}^{\infty} \rho^t C(H_t, w, l), \\
H_t &\in [0, B_t]
\end{aligned}
\tag{1}
$$

where p is the price of the biological product, ρ is the discount factor,[4] H_t is the harvest in year t, $R(\cdot)$ is the *gross* present value of the resource, $C(\cdot)$ is a cost function that includes collection costs and the opportunity costs of maintaining and preserving the resource (w and l are time-invariant wage and land rental rates, respectively), and B_t is the total production of the resource for year t. Successful resource commercialization increases demand for the biological product, thereby increasing p and locals' valuation of the underlying biota. Doubling or tripling of resource prices, as has occurred with argan oil, makes natural capital a more attractive investment for local resource owners, through conservation of existing forest, planting of new trees, or both. This logic permeates most arguments for resource commercialization as a conservation strategy.

At least five important assumptions underpin this tidy logic. First, it is assumed that prices increase for the resource owners, thereby increasing the net present value of the forest stand. Although this may occur on average in a region, the organization of product marketing

[4] This discount factor is equal to $1/(1+r)$, where r is the discount rate.

may exclude important subpopulations of resource owners who consequently fail to capture benefits arising from higher unit prices post-commercialization.

Second, resource owners must have a modicum of tenure security. Even when the price received by locals increases, those with imperfect or poorly enforceable claims may not be able to exclude others from sharing in the harvest.

Third, so long as time preferences cause people to discount the future, the biology of the resource, as manifest in the production sequence $\{B_t\}_{t=0}^{\infty}$, dictates the magnitude of the increase in resource net present value. If product does not arrive for many years, as is the case with some slow-growing species such as argan trees, then even a tripling of price yields only meager gains because the base period resource value is so low due to discounting. Just because the resource's net present value increases at the margin does not mean that it increases much, let alone enough to warrant conservation or deliberate reforestation.

Fourth, when B_s is affected by the sequence of harvest decisions $\{H_t\}_{t=0}^{s}$, then over-harvesting can affect the resource's recruitment rate. Put more simply, if people harvest more of an increasingly valuable natural product that is also essential to regeneration of the resource, as is the case for nuts, then even a forest protected from tree cutting may collapse in time.

Fifth and finally, the prevailing resource commercialization logic assumes that the increased wealth generated by increased prices and resource values provides economic incentives to which locals, given their social and cultural norms, respond predictably and desirably. Furthermore, indirect effects associated with increases in wealth such as tenurial change or investment in other assets that threaten the target resource are ignored. The sections that follow explore these four assumptions in turn.

We exploit data collected during fieldwork in the AFR, including a household survey in the Smimou *Caidat,* a county-like administrative unit located in the Essaouira Province in southwest Morocco. Villages were stratified by forest density (low, average and high), then two villages randomly selected from each stratum.[5] Households within selected villages were then stratified according to the number of *agdal* rights held and then randomly selected from each *agdal* wealth category. The survey was fielded separately with the male and female heads of 117 households.[6] Household data indicate that livestock, primarily goats, and argan oil extraction are the most important productive activities, followed by barley and olive production. Household average goat herd size was 11, while the mean household argan tree use (either via ownership or usufruct) was 345. Lybbert et al. (2002) present complete descriptive statistics of these data and discuss the welfare effects of the argan oil boom in some detail.

IV. Commercialization of Argan Oil: Are locals capturing the full value of their trees?

The indigenous tribes of the AFR have relied for centuries on argan oil as a key element of their diet, as a skin and hair moisturizer,and as a treatment for minor wounds and ailments from rashes to diabetes. Yet not until perhaps 20 years ago were technical analyses performed on argan oil to determine the veracity of traditional Berber claims. Subsequent scientific studies consistently provide evidence supporting a number of these claims, sparking entrepreneurial activity by those

[5] To sort villages in the Smimou *Caidat* into low, average and high argan forest density, we consulted local and regional forestry officials in conjunction with topographical maps and a 1996 forest inventory.

who foresee lucrative non-traditional markets for argan oil's nutritive, dermatological and even medicinal properties.

European cosmetic companies were perhaps the most keen and agile of the investigators. In the early 1990s these companies began adding small amounts of argan oil to their moisturizer products. By 1995, at least three cosmetic companies were using argan oil in their products: Galénique (product: Argane), Yves Rocher (product: Acaciane) and Colgate Palmolive (product: dermatological soap, Antinéa) (Charrouf, 1995). Commercial argan oil distributors also seek to tap the high-value, domestic market of tourists and middle and upper class urban dwellers. Today, the two most common argan oil products are edible (cooking or salad) oil and cosmetic oil, marketed as a moisturizer and a treatment for wrinkles and a variety of dermatological ailments (e.g., acne, abrasions, rashes).

The demand for high quality argan oil has expanded rapidly in recent years. Upscale restaurants in New York, London and Paris feature the nutty oil (e.g., warmed and drizzled over goat cheese) (Fabricant, 2001). Specialty shops and internet vendors have sprung up, selling the oil for upwards of $200/liter with claims that it is the world's rarest and most expensive edible oil (e.g., www.exoticaoils.com, www.arganoil.com, www.gourmetoil.com). An argan oil cooperative had revenues of over $100,000 in 2000 with 60% of its sales over the internet (see www.targanine.com), mostly to distributors in Europe and North America (Zoubida Charrouf, personal communication). Amidst this dramatic market expansion, however, the price of traditionally extracted argan oil in the AFR has changed little (Lybbert et al., 2002).

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[6] Sampling proportions across villages ranged from 23-34%. We use the resulting sampling weights to compute unbiased estimates of the population parameters we report for the whole AFR.

Exporters quickly recognized that artisinal argan oil extraction and marketing were ill-suited to higher value markets. Consumers in these new, higher-price markets expect a purer, higher quality oil and slicker packaging than do traditional argan oil consumers in the AFR. Thus, argan oil could not simply be purchased at *souk* from local producers and resold for a premium in other markets. More sterile, mechanized extraction and more sophisticated marketing strategies were needed. The induced change in processing and marketing has meant that locals participate in the argan oil boom almost exclusively by supplying argan fruit.[7]

Since argan fruit supply is inelastic in the short run, increased demand in argan fruit markets has driven up fruit prices, from around 0.5DH/kg in the mid-1990s to over 1DH/kg by the end of the decade. However, AFR locals have not uniformly benefited from increasing argan fruit prices. Even with higher prices, argan fruit's low value-to-weight ratio makes long distance transport to market unprofitable. The middlemen who have emerged to supply the high-value argan market transport the fruit in lorries and therefore stick to markets easily accessible via good roads. This favors low density forest dwellers, whose greater proximity to roads and larger markets gives them greater access to argan fruit markets than villagers in high density forest zones.[8] This is of course good for conservation, all else held equal, since the forest is most threatened in the lower density forest margins.

[7] Traditionally, locals commonly fed whole argan fruit to their livestock, primarily goats, and then harvested the argan stones from the manure. These stones were then cracked to remove the oil-rich nut which was then crushed to extract the oil. Emerging high-value producers, concerned about the possibility of residual impurities from goat ingestion, are willing to purchase whole argan fruit. The attached pulp is essentially a guarantee that the fruit has not been ingested by livestock. For more on various signaling mechanisms to resolve asymmetric information in argan product markets see Lybbert (2000). In addition, locals face severe infrastructure and credit constraints, which preclude most locals from participating directly in the emerging markets via mechanized extraction (Lybbert et al., 2002).

[8] Our survey data show that while high density forest households sold twice as much argan oil at *souk* as mid- or low density forest households, not a single high density household sold argan fruit. In contrast, many households in mid- and low-density forest regularly sold argan fruit.

The first assumption of the commercialization-led conservation logic also requires tenure security. As discussed previously, tenure is seasonal in the AFR. During the off-*agdal* season, locals theoretically cannot exclude others from using their *agdal* tracts. Nonetheless, the increased value of mature trees has given rise to a recent enclosure movement in which locals are constructing permanent barriers around their *agdals*, a trend we discuss further in the next section.

The distribution of argan forest rights does not rely on official titling procedures and, in practice, is not always respected. There are often disputes between different villages over forest use. Locals commonly cultivate barley, an important staple food, around the argan trees in their *agdals*, partly as a public declaration of their *agdal* rights. Unfortunately, continuous cropping of barley is a costly form of establishing and maintaining tenure since without significant fertilizer amendments it quickly depletes key soil nutrients in this arid region. Continuous barley cultivation thus increases short-term tenure security at the cost of long-term sustainability of the argan forest, directly by impeding the natural regeneration process and indirectly by leaching soil nutrients. Furthermore, the desire to establish greater security over one's *agdal* via barley cropping intensifies as the value of argan fruit increases.

Locals' tenure insecurity is illustrated by the periodic migration of massive Saharan camel and goat herds into the AFR.[9] During the summer of 1999, which followed a low rainfall year, over 7,000 camels owned by a wealthy pastoralist from the disputed Western Sahara slowly trekked through the forest south of Essaouira, wreaking havoc to the forest during the *agdal*

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[9] These massive and destructive migrations have both a climatological and a political explanation. Climatologically, these livestock owners were bringing their herds north in response to the paucity of fodder in the Western Sahara, the result of an unusually dry winter and spring. The migrations were ignored because of the political conflict surrounding the Western Sahara. No local official dared impede them for fear of instigating what could quickly escalate into a national crisis.

season. The camel herders completely disregarded local villagers' *agdal* rights, adamantly defending their right to the relatively abundant fodder. The state offered no support to the locals.

In summary, AFR residents are unlikely to capture the full value of argan oil commercialization because (1) they are not reaping the full increase in price due to market entry barriers that relegate them to fruit supplier status or leave them out of the market altogether and (2) their expected future harvest is less than the expected production of the tree due to tenure insecurity. Imperfect institutions and markets conspire to limit the transmission of commercial incentives to private resource managers in settings such as the AFR. Furthermore, locals' rational efforts to increase tenure security through barley cultivation may have negative implications on forest sustainability. As we discuss in the next section, the enclosure movement bodes well for conservation in *agdal* areas, but poorly for *azroug*.

V. Biology Matters

In those areas where AFR residents enjoy both increased prices for the fruit they sell and reasonably secure property rights in argan trees, do higher prices induce conservation, either through planting new trees or protecting existing ones? This section explores that question in greater analytical detail. We begin by estimating a yield function for the tree, then we incorporate discount rates and fruit prices to estimate the change in the present value of argan trees. Yield functions are difficult to estimate for argan because the tree has a unique mechanism for coping with frequent droughts. During unusually dry years, the argan tree goes dormant, stores its needed reserves deep in its root system and produces neither fruit nor foliage (Bani Aameur, Louali, and Dupuis, 1998). Then, once there is sufficient precipitation, the trees begin producing again. Because it does not produce rings during dormant periods, there is no reliable record of an argan tree's age. Consequently, argan's fruit yield-age relationship has yet to be explicitly researched.

Table 1 displays the meager available evidence on argan tree productivity, derived from researchers' own sampling of established trees and from surveys of AFR households (e.g., DePonteves, 1989). Unfortunately, not a single reference links observed fruit production with a precise age of the tree. These estimates provide information enough to fit crude argan fruit yield functions $B_i(t|\tau) = \{B_{it}\}_{t=\tau}^{T}$, which can be used to assess the value of a τ year old argan tree's remaining fruit production. The harvest and opportunity costs that AFR locals face are not well documented, but since the cost function in equation (1) is unaffected by fruit price changes – and there has been no discernible change in the opportunity costs of land or labor – the change in net present value of argan trees due to higher prices for argan fruit reduces to the change in the *gross* present value of fruit production ($R(\cdot)$ in equation (1)). An upper-bound on the gross present value for any τ_0 year old tree occurs when the annual harvest is maximized (i.e., H_t=B_t for all t), given by:

(2) $$R_i(p, \{H_t\}_{t=0}^{\infty} | \tau_0) = R_i(\tau_0) = p \cdot \sum_{t=\tau_0}^{T} \rho^t \cdot B_i(t | \tau = \tau_0)$$

where the i subscript reflects different estimated yield functions in kilograms/tree, p is the price of argan fruit in dirhams (DH) per kilogram, ρ is the discount factor,[10] and T represents the

[10] We initially assume r=0.105. While prevailing inflation and nominal interest rates in rural Morocco over the past few years have averaged 4% and 9%, respectively, medium term agriculture loans from the Moroccan government have historically carried a 10.5% interest rate (DePonteves, 1989). Lending rates in the informal markets are surely higher, so r=0.105 is likely conservative. The sensitivity of these calculations to the discount rate is discussed later in this section.

lifespan of an argan tree. $R_i(\tau_0)$ represents the *net* present value of a τ_0 year old tree when harvest costs are zero, thereby establishing the maximum net present value of a τ_0 year old argan tree.

We consider two different candidate functional forms. The first, $B_1(t)$, is a piecewise linear function with a constant positive growth rate after an initial zero-production period, followed by constant production and then a linear decline in production. The second is an exponential function of the form $B_2(t) = e^{a-b/t}$, where *a* and *b* are estimable parameters. Argan fruit production is highly sensitive to precipitation and, as illustrated in Table 1, there is no clear consensus about the production profile of an argan tree. We use these rough production estimates to calibrate two yield functions. To represent the diversity of the Table 1 production estimates, we rely on a different set of references when fitting $B_1(t)$ and $B_2(t)$, respectively. Figure 2 shows the resulting estimated yield functions. These are purely numerical examples consistent with scant available information on the tree and are intended to provide not precise estimates but only a qualitative sense of why increased fruit prices might not stimulate conservation.

The estimated gross present value of an argan tree's *annual* fruit production is shown graphically in Figure 3. These present values assume $p=1$, roughly the 1999 post-commercialization price per kilogram of dry fruit.[11] At the time of germination (i.e., $\tau = 0$), future production is discounted significantly enough that the maximum present value of annual fruit production per tree is less than 2 DH. The average daily wage for a male laborer is presently about 35 DH. In contrast, the maximum gross present value of the annual fruit production of a mature argan tree (e.g., $\tau = 60$) is about 40 DH.

[11] This post-commercialization price is nearly double the historical average for argan fruit (Lybbert 2000).

The maximum *total* gross present value of the remaining fruit production of an argan tree of age τ (i.e., the sum over $t=0,\ldots,200$ of the annual present values shown in Figure 3), from equation (2), for $R_1(\tau)$ and $R_2(\tau)$ are only 45 DH and 5 DH, respectively, at germination (Figure 4). Of course, the incentive to plant a tree depends on its *expected* net present value, the total net present value of a newly planted tree times the probability of the sapling surviving. From past experience, survival rates for transplanted argan saplings are often below 20% (see Alaoui, 1997). Thus the *expected* maximum gross present value of an argan seedling is only 1-10 DH. Even without data on the non-labor costs of tree establishment and ignoring the effect of risk aversion on incurring sunk costs in the face of uncertainty (Chavas, 1994), this is surely insufficient to cover the opportunity cost of labor to plant and tend the tree, roughly 35DH/day for adult males in this region. Even a few hours spent planting and tending the tree would make it unremunerative. No data exist on the labor requirements over time to establish and maintain trees. But under the highly speculative assumption that properly establishing a tree takes one-half day and maintenance takes another half day/year, prices would need to increase at least 15-20 fold further – having already doubled in the wake of the upscale argan oil market boom – in order to make argan tree planting profitable. Small wonder, then, that few locals seem interested in the free argan seedlings offered by the state's *Service des Eaux et Forets.* Because the tree grows slowly, even the maximum *gross* present value of fruit production at germination is too small to make planting argan trees pay.

Given the imprecision of our yield function estimates, it is helpful to analyze the sensitivity of the gross present value of an argan tree, $R_i(\cdot)$, with respect to changes in key calibration points and in the discount rate. Table 2 shows these gross present values, $R_1(\tau=0)$ and $R_2(\tau=0)$, under three optimistic scenarios that seemingly make planting an argan tree extremely attractive. Relative to the original calibration values, doubling the maximum annual harvest, B_t, or reducing the time to maximum harvest by half doubles $R_1(\tau=0)$, but less than doubles $R_2(\tau=0)$. Not surprisingly, a much larger increase in gross present values is achieved when the discount rate is reduced from 0.105 to 0.05. Even in this best of the best-case scenarios, however, local reforestation is unremunerative assuming total annual labor costs are roughly half day/year (17.5DH). Under the equally-optimistic assumption of 50% survival rates, the already higher price of argan fruit would have to more than triple *at least* before a risk averse local would rationally plant argan trees.

Survey evidence of AFR resident preferences and behaviors corroborates the preceding findings. Several trees (e.g., olive, carob, argan) are biophysically-suited to the arid conditions of the AFR. Recognizing that AFR locals can choose to plant any of these trees on their private land, to which they possess secure tenure, we asked both male and female household heads, "If you were given a tree to plant on your property, what kind of tree would you prefer?" Olive trees were overwhelmingly most desired (Table 2). Male respondents also preferred carob trees to argan. So did female respondents outside the high density forest zone, none of whom has ever planted or watered argan trees.[12] Indeed, high density forest residents were practically the only ones to express a preference for argan trees. No household in low density areas, where the forest is most threatened and where argan fruit prices have increased significantly, even mentioned the argan tree in response to this open-ended question. Both analysis based on rough estimates of argan yield functions and survey evidence suggest that the argan oil commercialization boom has prompted no spontaneous local reforestation, due most likely to the tree's slow-growing biology.

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[12] Administrators at the Essaouira regional office of the *Service des Eaux et Forets* confirmed that carob seedlings are consistently in higher demand than argan seedlings because they more quickly produce

In contrast to argan seedlings, survival rates and fruit yields for existing, mature argan trees are high, and thus expected net present values are as well. Higher argan fruit prices have increased the value of mature trees, prompting locals to protect those in their *agdal* more vigorously. Figure 4 illustrates that existing trees have indeed become very valuable. For example, the total gross present value of a 60 year old argan tree's remaining fruit production doubled to 250-400 DH/tree, based on $B_2(t|\tau = 60)$ and $B_1(t|\tau = 60)$, respectively. This increase is equivalent to one to two weeks' earnings on the local labor market, easily enough to induce AFR residents to devote an extra couple of days' time to building fences, especially since a single enclosure usually encircles several mature trees.[13,14] AFR locals appear willing to invest time and effort in enclosing their existing trees with permanent *agdal* barriers although they seem unwilling to invest time and effort in planting even free argan seedlings.

Survey evidence again corroborates the implications of these estimates. Male household heads were asked whether they would cut down the argan trees on their property for either agricultural conversion or for the value of the wood if the *Service des Eaux et Forets* gave them permission. The majority responded that they would not cut their argan trees for either purpose, although the pressure to convert forest to agriculture appears significantly greater in low density villages (Table 2). These responses are consistent with the general observation that the historical threat of direct conversion or clear-cutting did not emanate from locals and faded long before

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marketable fruit and because a carob processing plant recently located in Essaouira, creating a substantial local market for carob fruit.

[13] The average density of the argan forest is about 30 trees per hectare (Rahili, 1989).

[14] These barriers typically consist of a stone wall (about a meter high) with piles of dead argan branches on top. The barrier can be nearly 2 meters tall. The thorns of the argan branches can prevent even goats from getting through. Often barriers are used in addition to barley cultivation to jointly secure and enforce tenure.

current argan oil commercialization efforts. Conserving the argan forest now requires addressing local threats such as overbrowsing.

We asked female household heads, first, how frequently they allowed their goats to climb and browse in argan trees and, second, to assess whether overgrazing and overbrowsing were problems in the argan forest. To the first question, nearly all (95%) browsed their goats in argan trees frequently, which likely reflects the widespread perception that livestock are the most valuable assets to own in the AFR and that alternative browsing/grazing areas are quite scarce. Responses to the second, overgrazing question were more instructive. In the high density forest village*s*, where trees are plentiful and the commercial benefits of argan fruit marketing have remain largely unchanged in the wake of commercialization, women did not perceive overgrazing to be a problem (Table 2). By contrast, roughly half the respondents thought overgrazing was a problem in the low and middle density regions, where the price increases due to commercialization have been significant.

Key informants report that increased argan fruit prices have indeed induced more forest-friendly browsing practices. The *Caid* (regional appointed authority) of Tamanar observed that since the arrival of the argan oil cooperative, locals are more hesitant to allow their goats to browse in argan trees because they know that every piece of argan fruit their goats digest is one they could have sold to the cooperative.[15] Other interviewees made similar observations regarding areas where fruit markets were accessible to collectors. So households may be trying harder to keep their own goats out of their *agdal* trees, reinforcing the induced enclosure movement to keep others' goats out of one's trees.

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[15] For more information about the argan oil cooperatives that have been created and their impact on locals' participation in argan oil commercialization in the AFR see Lybbert et al. (2002).

In summary, the biology of the argan tree makes the present value of a newly planted tree low. Even a very robust increase in fruit prices has too modest an absolute effect on tree values to induce reforestation. Mature trees prove worth conserving, however, and resource commercialization and attendant increases in tree values have induced both an enclosure movement and some change in livestock browsing/grazing practices. Nonetheless, in the longer run, additional considerations come into play, as we now discuss.

VI. Harvest Decisions and Productivity

Reforestation of argan is a very difficult proposition. The tree's extensive root system extends deep into the soil at a remarkably young age, making transplanting difficult and rarely successful. Argan seedlings also appear extremely vulnerable to various fungi (Bani Aameur, 1997). Whatever the explanation, argan reforestation projects are plagued with exceptionally low success rates. In one experimental reforestation effort, only 11% of the argan seedlings planted survived for more than three months (Alaoui, 1997). Since no appreciable human reforestation is currently taking place or is likely to be successful in coming years despite considerable ongoing research in the area, the future of the argan forest depends entirely on natural regeneration. This requires that at least some fruit remains uncollected. Increasing fruit prices could negatively and directly affect the forest by making fruit too valuable to leave behind. Some researchers worry that the long term sustainability of the argan forest has already been jeopardized by nearly complete fruit harvests in recent years (Bani Aameur, 1997). Moreover, some claim that the microclimatic conditions have changed sufficiently as a result of thinning canopies (less shade) and overgrazing (less organic litter on the forest floor) as to seriously hamper the natural regeneration process (Zahidi and Bani Aameur, 1996).

Our survey solicited local perceptions of this prospective overharvesting and regeneration problem. Table 3 reports that the proportion of female household heads who believe all the argan fruit in the forest is collected is decreasing in forest density, with more than half the households in more stressed, low density forest zone 'strongly agreeing' with the assertion that all fruit in the forest is collected. Where fruit is scarce and collectors have good access to markets now returning higher prices, few if any fruit are left to seed forest renewal.

In the short run, decisions about *how* to harvest are just as important to forest productivity as decisions about how much to harvest. Traditionally, locals harvested fruit from argan trees either by sending goats into the tree to browse on the fruit and later collecting the valuable stone in the goat manure or by waiting for the fruit to fall from the tree. As the fruit becomes more valuable, however, anecdotal evidence suggests that locals turn to more aggressive techniques, such as knocking fruit from the tree using sticks and stones. More aggressive harvesting methods, seemingly more common in areas with relatively weak tenure security, can damage trees and hurt natural forest regeneration. The relevant question is not, however, whether aggressive harvesting is harmful to the forest, but whether it is more harmful than the traditional alternative of goats browsing the forest canopy. While the harm inflicted by goats almost surely outweighs the collateral damage inflicted by the sticks and stones of aggressive harvesting, these harvest techniques are equally-complete and both pose a threat to natural forest regeneration.

VI. Responses to Incentives & Indirect Effects

Suppose, hypothetically, that locals did reap significant benefits from resource commercialization, and that harvesting practices neither harm the existing resource nor threaten the natural regeneration of the resource (i.e., that all three previous assumptions implicit to the commercialization-driven conservation strategy hold). Is it then safe to assume that local conservation will proceed? It depends on how locals respond to the increases in wealth they then enjoy, which depends in part on the best available investment options and in part on the social and cultural context.

In local Berber culture, there exist two competing legends concerning the origins of the argan tree. The first traces the tree's origin to the prophet Mohammed, who was given stewardship over the tree by Allah and told to plant it liberally throughout southwestern Morocco. In this narrative, Mohammed is responsible for the providence of the argan tree along with all its bountiful uses. In direct opposition, the second legend traces the argan tree to Satan, who was permitted to use the tree to afflict and torment Berber women. Women subscribing to the second narrative explain that the tree is thorny and demands so much of their time that it distracts them from their other responsibilities. Only Satan could be responsible for such a pestilence, they say. Importantly, neither of these myths places ultimate responsibility for the argan tree with the locals. Locals consider the argan tree 'wild', and seem to have never invested much time or effort in tending argan trees. In contrast, domesticated olive and carob trees do capture the locals' attention and investment.

This perception of the argan tree is fundamental to the commercialization-conservation link. Berbers' routine denial of responsibility for argan trees diminishes the likelihood of direct individual investment in them. Instead they invest any gains in olive or carob trees or, especially, in goats. This may have significant indirect effects on conservation of the argan forest.

While these indirect effects are difficult to describe quantitatively and rigorously, they can be discussed anecdotally. Livestock are the most desired form of household wealth in the AFR. Relatively poor households typically invest in small ruminants such as goats and sheep whereas relatively wealthier households hold much of their wealth in larger livestock such as camel, mules and cattle. Given that non-farm options are scant and crop cultivation offers poor returns in the AFR, livestock will continue to be the primary household investments. While some of the proceeds might conceivably be invested in additional *agdals* of argan trees, the market for these assets has historically been quite illiquid. Since stocking densities and forest stress are positively correlated, this indirect effect bodes poorly for argan forest conservation. The low density forest zones in which AFR residents have enjoyed some windfall gains from the argan oil boom are the places where the forest can least afford the added pressure of still-higher stocking rates.

Resource commercialization might also indirectly affect tenure arrangements in the AFR. As fruit becomes more valuable and *agdal* holders become more protective of their fruit (or enclose their *agdal* tracts outright), what was previously communal forest land during the off-*agdal* season is effectively removed from the common pool resources. This de facto change in tenurial arrangements, though controversial, is increasingly common and appears to be gaining acceptance. In the short-run, excluding neighbors from traditional off-season access to *agdal* trees decreases the aggregate browsing pressure on the *agdal* forest. The net short-run conservation effect of this tenurial evolution thus appears positive in *agdal* areas. But the spatial reallocation of animals almost surely exerts significant negative effects on the more stressed *azroug* lands.

Locals are unlikely to protect *azroug* trees for two reasons. First, common property management problems have left *azroug* trees generally less productive and more degraded than *agdal* trees, so the present value of their fruit production is less. Second and relatedly, there are few if any traditional cooperative maintenance and management arrangements in the AFR, so *azroug* trees fall prey to classic commons problems: everyone has an incentive to exploit the tree but no one has an individual incentive to conserve it, underscoring an institutional weakness that underpins part of the conservation challenge in the AFR.[16]

Finally, it is conceivable that the market for *agdal* rights will become more liquid as the value of these assets increases. Such a market could exacerbate the already regressive distribution of *agdal* rights (Lybbert et al., 2002) as the relatively wealthy households benefiting most from higher fruit values invest in yet more *agdal* rights, leaving poor households with access only to *azroug* forest becoming increasingly degraded by the growing and relocated herds of the relatively wealthy. Besides boding poorly for these communal areas of the forest, this could have further impacts on the forest as poor households make desperate attempts to survive with little legal access to the productive *agdal* forest.

In sum, the increased wealth brought to the AFR by resource commercialization seems unlikely to be invested in planting more argan trees, for both economic and sociocultural reasons. Increased wealth will likely be invested instead in additional livestock, the primary cause of degradation in the argan forest. Higher fruit prices have induced changes in the tenure system of the forest. While these changes might improve the conservation of *agdal* areas of the forest, the net effect is ambiguous due to more concentrated exploitation of *azroug* sections of the forest. Additional tenure changes such as more liquid *agdal* markets, though presently hypothetical, could also further affect the conservation effect of argan oil commercialization.

VII. Conclusion

This paper has assessed the net local forest conservation effect of a commercial boom in the market for Morocco's argan oil. There are at least five important assumptions implicit in the standard logic to market-based approaches to conservation. The ability of resource commercialization, whether via ecotourism, bioprospecting, or commercialization of non-timber forest products, to translate into appreciable net local conservation hinges critically on these underlying assumptions.

In the argan oil case, these assumptions seem tenuous. Many locals are not capturing the full value of the more valuable argan oil due to market barriers and tenure insecurity. Even with recent fruit price increases, reforestation does not appear to pay because of the slow-growing nature of the argan tree. Conversely, protecting existing argan trees seems to pay quite well. This helps explain why locals are largely uninterested in planting argan trees, but in the low density areas enjoying increased argan fruit prices due to commercialization, they are willing to invest in protecting their existing trees with permanent enclosures. But it is unclear that local conservation is the logical consequence of this greater valuation. While *agdal* enclosure bodes well for the

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[16] While *azroug* is rarely, if ever, reclassified as *agdal*, increasing fruit prices could possibly induce such an institutional change in the long-run.

preservation of part of the argan forest, displaced livestock browsing and grazing and the incentives associated with local forest tenure seem to contribute to localized degradation in the communal *azroug* forest. Moreover, harvest decisions are not exogenous to the productivity of the argan tree. Specifically, the forest relies almost entirely on natural regeneration since reforestation efforts have largely failed. Unfortunately, overharvesting already threatens natural forest regeneration and could intensify as fruit prices increase. More aggressive harvesting techniques, if broadly adopted, could also threaten the short run productivity of the forest.

The argan oil boom in southwestern Morocco presents a promising case study for analyzing the conservation effect of resource commercialization because locals produce argan oil, possess well-established (if not always secure) rights to the forest and pose the primary threat to the forest. That critical implicit assumptions fail to hold in this case is evidence of the high standard imposed by these assumptions. The case of argan oil commercialization thus serves as a cautionary tale about the challenge of using market-based efforts to induce local conservation in the tropics. Before markets can be expected to induce direct reforestation, there are fundamental biological and institutional issues that must be addressed. Despite considerable ongoing research in Morocco on the biology of the argan tree, reforestation and cultivation remain significant impediments to the conservation of the argan forest. Likewise, insecure tenure, including incursion from large herds from outside the region without protection from the state, threaten the trees and undermine incentives to invest in them. Meaningful conservation will therefore require investment in research and extension that seek to improve the management of the argan forest. Market-based mechanisms are no substitute for these fundamental conservation investments.

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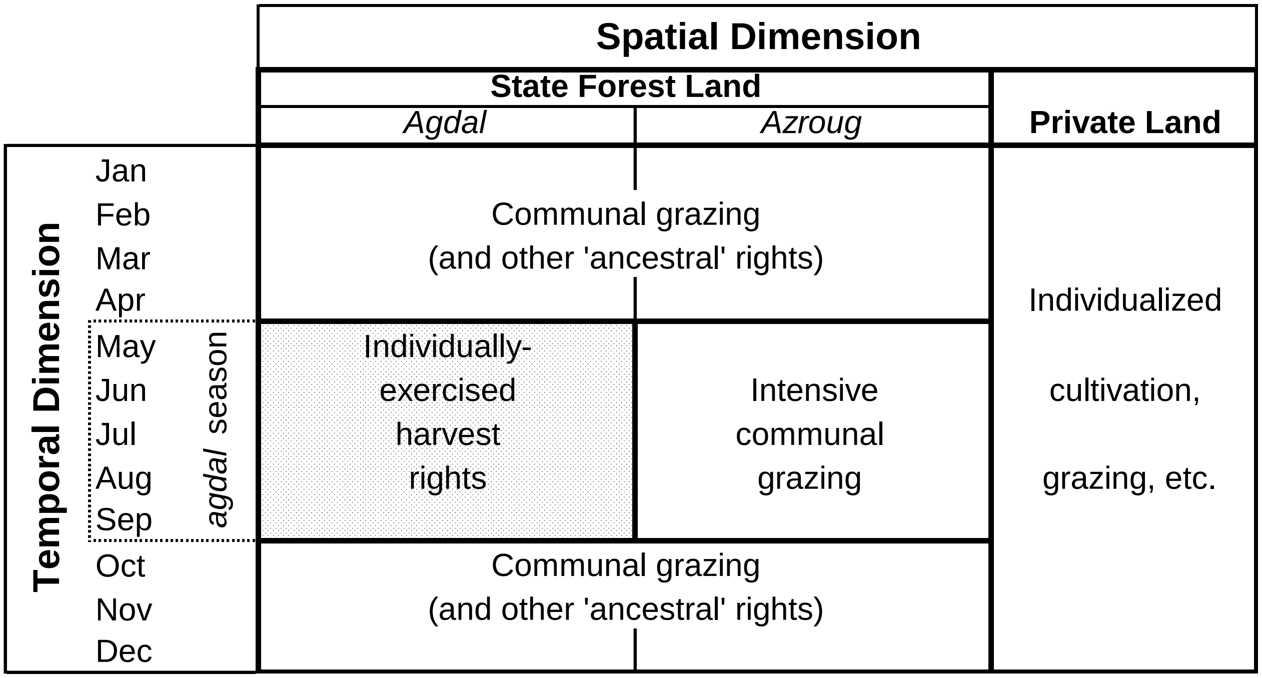

Figure 1 Dimensions of argan forest tenure (Note that the precise start and end dates of *agdal* season vary annually)

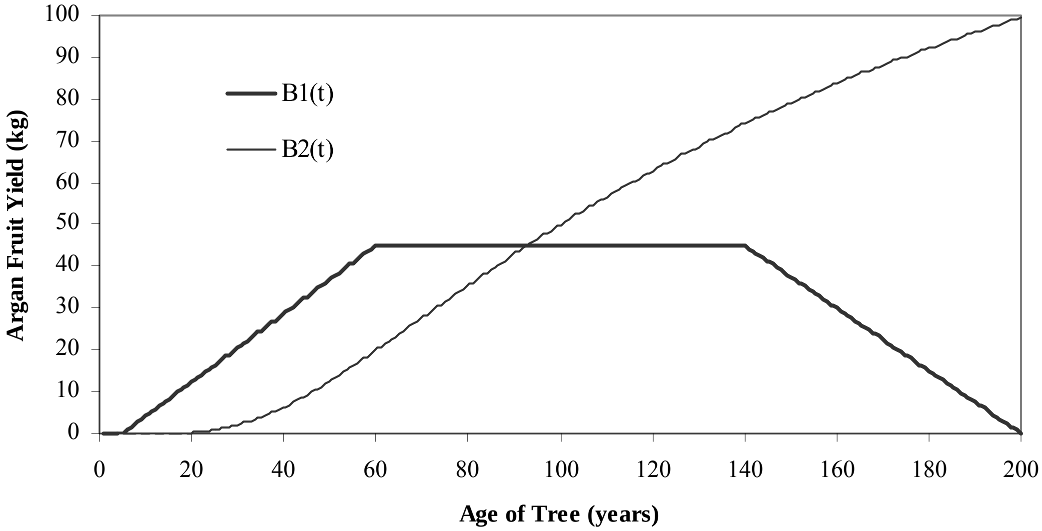

Figure 2 $B_1(t)$ and $B_2(t)$ yield functions

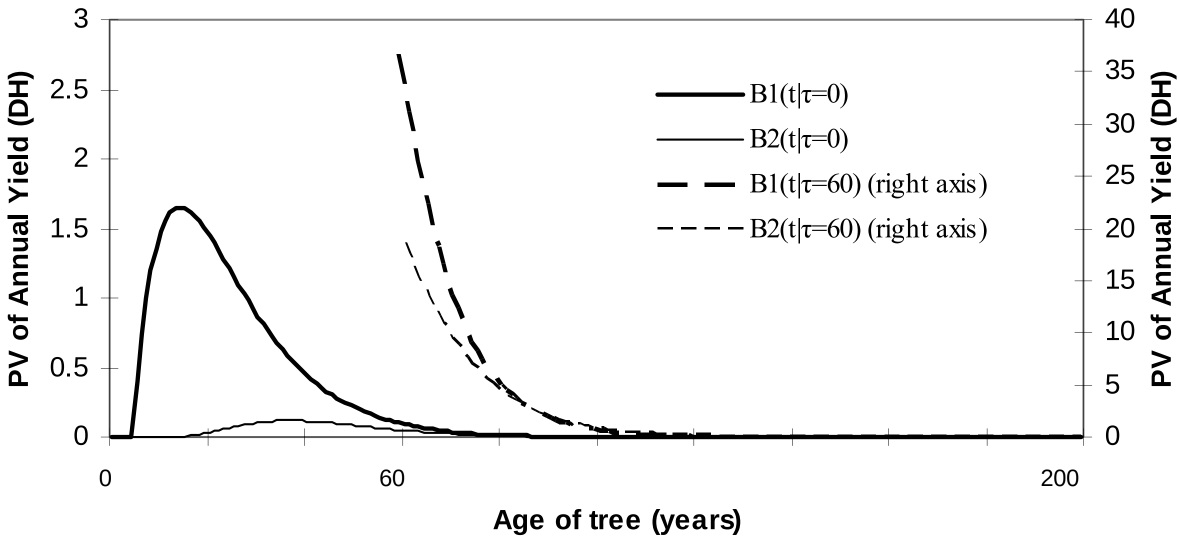

Figure 3 Gross PV of annual fruit production for $B_1(t|\tau)$ and $B_2(t|\tau)$ (p=1, r=0.105)

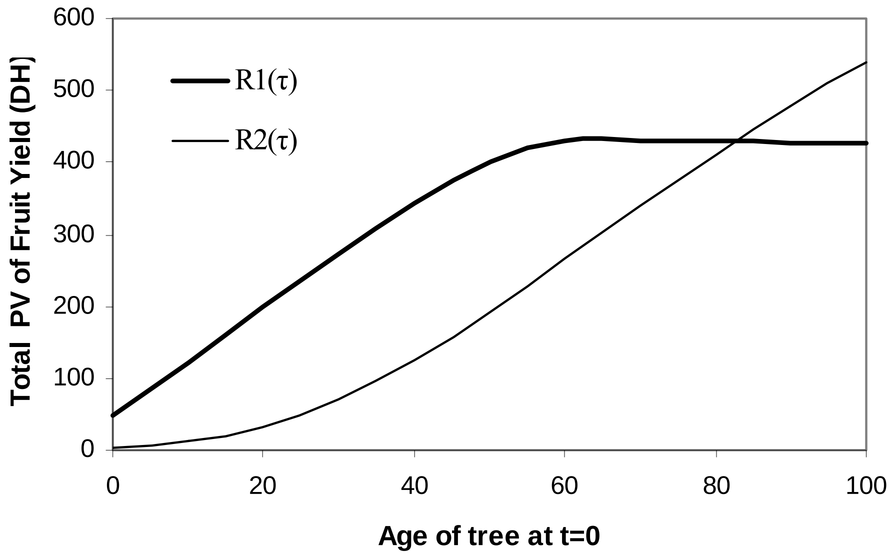

Figure 4 Total gross PV of fruit production for $B_1(t|\tau)$ and $B_2(t|\tau)$ (Note that τ is defined as the age of the tree at t=0 and hence represents the horizontal axis)

Table 1 Estimates of argan tree productivity and age

Reference	t (years)	Q(t) (kg/tree)
Rahali (1989)	Average	15
DePonteves (1989), Mhirit (1999)	Average	8-20
DePonteves (1989)	Maximum	100
Zahidi (1997)	Sample	3-45
Boudy (1950), DePonteves (1989)	5	Begins fruit production
Koubby (1997)	60	Production levels off
	140	Production begins to fall

Table 2 Gross present values of an argan tree under best-case scenarios

Scenario	Gross present values (DH) R_1 $(\tau=0)$	Gross present values (DH) R_2 $(\tau=0)$	PV of half day of labor/year (DH)
Original values	45	5	166
Double maximum B_t	90	6	166
Reduce time to maximum B_t by half	92	8	166
Reduce discount rate to r =0.05	230	69	350

Table 3 HHs' conservation-related characteristics and attitudes

		Sample	Density Categories		
			High	Mid-	Low
"If given a tree to plant, what kind would you prefer?" [a]					
Male Head	Carob	11%	21%	5%	5%
	Argan	3%	7%	-	-
	Olive	82%	69%	92%	84%
Female Head	Carob	7%	10%	5%	5%
	Argan	9%	24%	3%	-
	Olive	67%	52%	68%	81%
"If permitted, would you cut your argan trees to…"					
...facilitate agriculture?	Yes	10%	2%	8%	22%
	No	88%	98%	84%	78%
...procure wood?	Yes	8%	7%	13%	3%
	No	91%	93%	79%	97%
"Overgrazing is not a problem in the forest."					
	Agree	62%	83%	45%	54%
	Disagree	32%	12%	45%	41%
	N=	116	42	38	37

[a] Carob, argan and olive were the three most frequently cited species. Other species were also cited, but are not included here. Elsewhere non-response is responsible for question percentages totaling less than 100%.

Table 4 Household perceptions of harvest completeness

			Density Categories		
		Sample	High	Mid-	Low
"ALL argan fruit in the forest is collected.*"					
	Strongly Agree	36%	21%	32%	57%
	Agree	2%	2%	3%	-
	Indifferent	11%	24%	8%	-
	Disagree	16%	24%	16%	8%
	Strongly Disagree	34%	29%	39%	35%

* Percentages represent the female HH heads' categorical responses to this statement