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UTILISATION OF DOMESTIC FUELWOOD IN A TYPICAL VILLAGE OF INDIAN HOT ARID ZONE

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TEWARI, P., TEWARI, J. C., TRIPATHI, D., KAUSHISH, S., HARSH, L. N. & NARAIN, P. 2003. **Utilisation of domestic fuelwood in a typical village of Indian hot arid zone.** Farmers in arid tropics cultivate arable crops in association with tree species since time immemorial. These extensive agroforestry systems were capable to meet the fuelwood needs of the farmers only 25 to 30 years back. The tremendous increase in human and livestock population as well as associated demands in the last few decades is now marching towards fuelwood crisis. The present investigation reports the domestic fuelwood use pattern in Sar, a typical village of hot Indian arid zone. The availability of fuelwood with regard to consumption was 26.9% less for the whole village. At present, 68.6% wood came from extra-territorial resources. This deficit of fuelwood was being met largely by burning dry animal dung and to some extent by crop residues. If the present trend of fuelwood use continues, more and more animal dung will be diverted for domestic energy, particularly for cooking and heating. Some rural fuelwood management options are discussed.

Key words: Arid – thickets – crop residue – dung – fuelwood – household – landuse – livestock – *Prosopis juliflora*

TEWARI, P., TEWARI, J. C., TRIPATHI, D., KAUSHISH, S., HARSH, L. N. & NARAIN, P. 2003. **Penggunaan kayu api rumah di dalam satu kampung tipikal di zon panas dan gersang di India.** Petani di kawasan tropika yang gersang menanam tanaman suai tani bersama-sama dengan spesies pokok lain sejak zaman-berzaman. Sistem perhutanan tani yang meluas ini hanya mampu menampung keperluan kayu api petani sejak 25 tahun hingga 30 tahun kebelakangan ini. Pertambahan jumlah penduduk dan jumlah ternakan serta desakan yang berkaitan dengannya dalam beberapa dekad yang lalu kini menuju ke arah krisis kayu api. Kajian ini melaporkan pola penggunaan kayu api rumah di Sar, satu kampung tipikal di zon gersang di India. Kehadiran kayu api berdasarkan penggunaan adalah 26.9% kurang untuk keseluruhan kampung. Buat masa ini, 68.6% kayu datang daripada sumber luar wilayah. Kekurangan kayu api diatasi dengan membakar tahi haiwan yang kering dan kadang-kadang juga sisa tanaman. Jika arah aliran penggunaan kayu api sedemikian berlanjutan, lebih banyak tahi haiwan akan ditukar kepada tenaga rumah, khasnya untuk memasak dan pemanasan. Beberapa pilihan pengurusan kayu api luar bandar dibincangkan.

Introduction

The hot arid zone of India lies between 21° and 29° N latitude, and 70° and 76° E longitude, covering an area of 317 909 km^2, involving seven states, *viz.* Rajasthan, Gujrat, Punjab, Harayana, Andhra Pradesh, Karnataka and Maharastra. In Rajasthan

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state, hot arid areas are spread over the western and northwestern parts, which account for 61% (196 150 km^2) of the total Indian hot arid zone. They form the principal hot arid region of the country. The hot arid zone has its own fascination, unique features and resources, and problems too (Anonymous 1997). Sparsely distributed trees and other woody taxa with growth of arable crops (especially during monsoon season, as agriculture is predominantly rainfed) and/ or grasses in long stretches interspersed with distantly distributed village settlement are the actual features of Indian hot arid zone (Tewari *et al.* 1999).

The mixed crop-livestock farming, mixed livestock-crop farming and livestock farming form the spectrum of economic activities ranging from settled agriculture (in the true sense, settled agroforestry) to nomadism (particularly pastoralism). These farming systems have been described as true examples of extensive agroforestry systems (Malhotra 1984, Harsh *et al.* 1992, Saxena 1997, Singh *et al.* 1998, Tewari *et al.* 1999). Despite unfavourable environmental conditions such as low and erratic rainfall, dry atmospheric conditions, intense solar radiation, wide differences in seasonal temperatures, high wind velocity, immature and structureless soils, people in the hot arid zone of India have always cultivated arable crops by growing them with trees (Mann & Muthana 1984). Fuelwood has been used for thousands of years to provide domestic energy for heating and cooking in the hot arid zone of India. Despite so much development in other energy sources, particularly energy derived from fossil fuels, wood is still the main source of energy for cooking and heating in the rural areas of the Indian hot arid zone.

The severity of fuelwood depletion, referred to as the fuelwood crisis, has been recognised throughout developing countries and generally attributed to problems such as escalating human population (Davidson 1987), extensive deforestation for agriculture and food production (Pimental *et al.* 1986), high prices for alternative fuels (Midgley *et al.* 1986) and inefficiency of fuelwood stoves (NAS 1980). A wide gap between demand and supply of fuelwood existed in national scenario, with a nation-wide demand in 2001 expected to be 225 million m^3 against the estimated supply of less than 25% of this demand (Tewari *et al.* 2000). In the hot arid zone of India, fuelwood accounts for more than 70% of the supply of primary energy in rural areas (Faroda & Singh 1998). In such a state of affair, the situation should be very gloomy in the hot arid zone where forested area is virtually negligible. However, the supply situation of fuelwood against demand does not appear to be so serious at present because animal dung and crop residues are also burnt. The present paper attempts to discuss fuelwood use in a typical village of arid western Rajasthan with emphasis on the situation of the present demand and supply of fuelwood and other traditional domestic energy sources as well as future trends that are likely to emerge.

Methodology

The study village, Sar, is located 30 km southeast of Jodhpur. For assessing fuelwood use, a three-stage investigation was planned. In the first stage, a reconnaissance survey of the village was made and data related to area of village, landuse, human and livestock population were collected from village land as well as population and revenue records. This was followed by the selection of households for the study. A total of 150 households was selected randomly. However, efforts were made to give proportional representation to all castes and religious groups, and also all sections of society based on their economic status (low, medium and high income groups). This sample of 150 households represented 42.1% of the total household of the village. As in other villages of hot arid zone, the traditional extensive agroforestry was practised in the selected village, Sar. The entire village is rainfed and crops, especially pearl-millet, cluster bean, green gram, moth bean and sesame are grown during the monsoon season (July–October) in association with tree species. Therefore, in order to asses the density of woody species, the agricultural fields of selected farmers (households) were visited and sampled by point centre quarter method to work out the tree species composition (Mishra 1968) to avoid biasness which often occur with the quadrat method (Tewari & Singh 1985).

In the second stage of the study, a questionnaire was developed to collect information on fuel use, like source of fuelwood, time spent on fuelwood collection, quantity of fuelwood used to cook human and animal food in the morning, afternoon and evening during the different seasons, quantity of animal dung and crop residues used as fuel, time spent on cooking, and other sources of energy used for heating and cooking. The questionnaire was given to identified participants through personal interviews from the 150 selected households. In each household, the selected participant was a woman, as all the above tasks were carried out by women in rural areas of the hot arid zone of the country (Tewari 1997).

In the third stage, repeated on-the-spot checks were made to determine the quantity of wood used to cook food for humans and livestock, and also for heating. Of the 150 participating households, only 72 households (20.2% of the total households of the village) agreed to co-operate. Precautions were taken to give proportional representation to different castes and religious groups, and also households with different economic status. The quantity of dried fuelwood and other sources like animal dung and crop residues used in a day (24 hours) in the morning, afternoon and evening was recorded twice per household per season, i.e. summer (mid March–mid July), rainy + autumn (mid July–mid November) and winter + spring (mid November–mid March). Thus, six records of wood utilised in a household were done from mid July 1998 till mid July 1999.

When the cropping season is over, farmers lop and sometimes pollard trees in their agricultural fields (i.e. in November and December) and collect leaves for livestock fodder and wood for fuel. Between November and December 1998, all fuelwood collected from the trees in the agricultural fields of 72 farmers and from the village common land was quantified. Care was taken to include trees of all diameter ranges and species while quantifying the fuelwood production through lopping and/or pollarding. Besides this, head loads of wood (which were always *Prosopis juliflora* stems and shoots) collected by women from areas which do not come under village landuse were also weighed as and when possible throughout the course of the study. All the information gathered throughout secondary sources, questionnaire and repeated field checks to quantify the use of fuelwood and other

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traditional domestic energy sources like animal dung cakes and crop residues, and then calibrating the data as and when necessary (see Borah & Goswami 1997) made it possible for us to reach the logical conclusion regarding fuelwood utilisation pattern in selected village.

Results and discussion

Landuse

The majority of the land in the village of Sar is sandy plain. However, at certain locations the terrain is undulating. The total area of the village is 2327 ha, of which 81.7% is under arable crop cultivation (Table 1). The common grazing ground, i.e. village common land is restricted to only 11.2% of the area. About 165 ha of the village are rocky and undulating, in which sparse thickets of *P. juliflora* are found scattered. In the north and northwestern side of the village is 400 ha of semi-rocky hillock (wasteland) in close proximity to the village. Such wastelands are basically state government land and they do not come under the jurisdiction of 'village Panchayat' (local self-governing body elected through adult franchise). As such, government lands are neither managed by the state government and the 'village Panchayat' has no jurisdiction over them. These lands are left unmanaged. In the village Sar, the 400 ha of hillock consisted of only dense and unmanaged thickets of *P. juliflora*.

Demography

The village had a total of 356 households with a total population of 2614 (Table 1). The male: female ratio was 1.12: 1.0. Of the total population, 22.0% was under 6 years old, 16% 6–12 years old and 15.3% 13–18 years old. Thus, 46.7% population came under adult category, i.e. > 18 years of age. The average agricultural land per household was 5.3 ha, and 0.7 ha on a per capita basis.

Table 1. Landuse and demographic features of village Sar

Landuse	
Arable land including fallow	1902 ha
Village common (grazing) land	260 ha
Area not available for cultivation	165 ha
Total area	2327 ha
Demographic feature	
Total household	356
Total population	2614
Male	1385
Female	1229

Livestock

Next to land, livestock constituted the most important asset of the rural folks in the entire hot arid zone of India. Of the total livestock, sheep accounted for 41%, goats for 25.6%, cows for 12.9% and the rest of the livestock together constituted 20.5% (Table 2). Thus, the average total livestock per household was 22.1, and 3.0 as per capita basis. As sheep and goat basically survive on grazing, as well as grazing and browsing respectively, however, the available grazing land (in true sense, silvi-pasture) per animal was only 0.03 ha, which is far less as per the recommended carrying capacity of 3.13 sheep/ ha/ year (Harsh *et al.* 1992).

Table 2. Livestock population in village Sar

Animal	Total number	% of total
Cow	1011	12.9
Young cow	625	7.9
Buffalo	605	7.7
Young buffalo	294	3.7
Sheep	3222	41.0
Goat	2015	25.6
Camel	95	1.2
Total	7867	–

Fuelwood resources and production

In the villages of the hot arid zone of India, two major sectors comprised the fuelwood supply system: private collection from farmers' own agricultural fields and collection from extra-territorial areas which do not come under any landuse category of the village. Both sectors did not have any formal organisation in terms of rural forestry management. The supply system of fuelwood is neither documented nor monitored nor regulated in any part of the hot arid zone of India. The woody vegetation composition and fuelwood production in the private collection system (farmers' agricultural fields) were based on information gathered through questionnaires and field checks (Table 3). Not a single household purchased fuelwood from any source, although each household was primarily dependent on fuelwood for cooking food for human and animal as well as for heating.

At the end of the cropping season (November–December), villagers cut side branches and twigs (lopping) of available tree species in their agricultural field for fuelwood use and also for fencing. Our assessment revealed that on an average 8.17 trees/ ha were available on agricultural fields + village common land (grazing), of which 44.3% were trees of *Prosopis cineraria*, 34.4% bushes of *Capparis decidua* and 12.4% bushes of *Zizyphus nummularia*. The remaining 8.8% trees belonged to other species.

During the annual lopping cycle of woody species, the maximum dry fuelwood, on an average per tree, was recorded for *P. cineraria,* followed by *Azadirachta indica* and *Tecomella undulata.* The minimum dry fuelwood per plant was available from bushes of *Z. nummularia.* These findings of dry fuelwood production from different woody species of the hot arid zone of India through annual fuelwood lopping regime were in conformity with earlier findings, especially with regard to per tree fuelwood production (Shankarnarayan 1984, Tewari *et al.* 1989, Tewari *et al.* 1999). As it was virtually impossible to quantify *P. juliflora* thickets through field estimations and because participants did not respond satisfactorily regarding the quantity of wood of the species exploited for fuel purpose, fuelwood availability from *P. juliflora* thickets was quantified by repeated weighing of head loads carried by rural women folk as and when possible.

Based on the available tree density of different woody species and fuelwood production estimates from the resources available on the farmers' field and village common land (grazing), per hectare private dry fuelwood collection per year was 191.7 kg (Table 3). On an average, per household level, it was 1.2 t/ year and for the whole village, it was 414.5 t/ year. The extra-territorial fuelwood collection was of much higher magnitude than that of private collection because private collection was done during a particular period and stored for use especially during winter. Extra-territorial fuelwood collection was as per requirement of household and without any systematic procedures which farmers follow for private collection.

Table 3. Woody vegetation and fuelwood production by way of lopping and partial cutting of trees in village Sar

Species	Density (trees/ ha)	Fuelwood production (kg/tree/year)	Fuelwood production (kg/ha/year)	Calorific value (kCal kg^{-1})
Prosopis cineraria	3.62	48.0	173.76	4560
Capparis decidua	2.81	2.0	5.62	4650
Ziziphus nummularia	1.02	1.0	1.02	4800
Acacia senegal	0.30	9.0	2.70	4600
Tecomella undulata	0.19	16.0	3.04	3350
Salvadora oleoides	0.12	17.0	2.04	4232
Azadirachta indica	0.11	32.0	3.52	6000
Total	8.17	–	191.70	–

Besides above mentioned species, *Prosopis juliflora* wood is collected in very large quantity as fuel in the form of extra-territorial collection. A headload of collected dry wood of the species, on an average weighed 26.5 kg (calorific value = 4800 kCal kg^{-1}).

Fuelwood consumption

All the 150 participants responded satisfactorily to the questions asked regarding fuelwood consumption on day to day and season to season basis. Spot checks were made to quantify fuelwood use in 72 households, making it possible to reach near exact figures regarding average fuelwood and other bio-fuel consumption per household. Total household consumption in village Sar during the year of investigation was 1805.2 t of biomass, comprising air-dried fuelwood, crop residues and dung cakes (Table 4). On a per household basis, the average consumption of biomass worked out to be 5.1 t/ year or 0.7 t/ year/ person. This value of arid dried fuelwood + dry crop residues + dry dung cakes consumption was very close to the average per capita consumption of dry wood (0.7 t/ year) only in developing countries (WCED 1987).

On the basis of responses of participants (150 households) and quantification of wood used for cooking and heating (72 households), it was observed that fuel was consumed three times a day—morning, afternoon and evening. The consumption of fuel varied from season to season (Table 4). The maximum use of fuelwood and other fuel resources (crop residues and dry dung cakes) were recorded during winter + spring. The value of fuel use during winter + spring was 171% more than summer and 145% more than rainy + autumn season.

Table 4. Fuelwood consumption (including dung cakes and crop residues) patterns at different seasons and different periods in a day in village Sar

Period in a day	Summer	Rainy and autumn	Winter and spring
Morning			
Average per household (kg/ day)	4.52	5.43	5.49
Total village (t/ day)	1.61	1.93	1.95
Total seasonal (t)	196.54	238.00	263.31
Afternoon			
Average per household (kg/ day)	1.36	1.56	5.52
Total village (t/ day)	0.48	0.55	1.97
Total seasonal (t)	59.32	68.26	238.01
Evening			
Average per household (kg/ day)	4.77	5.51	6.80
Total village (t/ day)	1.70	1.96	2.42
Total seasonal (t)	207.56	241.33	292.82
Total annual consumption (t/ year)	463.42	547.59	794.14

The total fuelwood catchment of village Sar included about 3000 ha of surrounding wastelands and was the main source of extra-territorial fuelwood collection. On this land, nothing is available except dense bushy thickets of *P. juliflora*. The coppice shoot of this species was one of the major sources of fuel. On an average, a household collected *P. juliflora* shoot twice a week. A single day collection of dry fuelwood from *P. juliflora* in households ranged from 23.0 to 29.5 kg, with an average per household collection of 26.5 kg. Wood collectors, normally women, often cut the coppice shoots and leave them there to dry for three to four days before collecting them at their convenience.

Over 68% of fuelwood consumed in village Sar was of *P. juliflora* (Table 5). The wood of this species possesses a high air-dry density and consequently burns slowly, produces hot embers and emits heat for a longer period (Pasiecznik *et al.* 1999). More than 28% fuelwood need was met by private collection from *P. cineraria*. The remaining 2.9% of fuelwood was contributed by other tree species growing in the farmers' fields, i.e. from private collection. However, the extra-territorial fuelwood collection of *P. juliflora* was illegal because the entire land is under the possession of state government (either by revenue department or by forest department), but in the absence of any defined policy of state government, particularly of the forest department, no consideration is given to such massive exploitation of *P. juliflora*. As wood of this species makes very high quality charcoal, an unknown but substantial quantity of the *P. juliflora* wood has already been exploited by charcoal producers. Consequently, this most important source of fuelwood for the rural folks of arid and semi-arid tropics of the country is degrading continuously. The word degradation instead of depletion is used here because old growth of the species which eventually forms *P. juliflora* woodland has virtually disappeared and only currently 2- to 3-year-old coppice shoots were found to spread densely in the entire area as bushy thickets. Tewari *et al.* (2000) have also expressed similar views when discussing the degradation of *P. juliflora* woodlands in arid and semi-arid tropics of India.

Table 5. Proportion and quantity of fuelwood species used in all the households of village Sar (mid July 1998–mid July 1999)

Species	Estimated use (t)	% of total	% of household
Prosopis juliflora	905.66	68.6	100.0
Prosopis cineraria	375.67	28.5	82.7
Acacia senegal	5.84	0.4	44.0
Capparis decidua	12.15	0.9	39.3
Zizyphus nummularia	2.20	0.2	36.7
Salvadora oleoides	4.41	0.3	16.7
Tecomella undulata	6.57	0.5	10.7
Azadirachta indica	7.61	0.6	10.0

Fuelwood demand and supply: current scenario

The values of fuelwood consumption and availability derived from the available data for the village Sar exhibited a deficit of 485.04 t/year. Thus, with regard to consumption, availability of fuelwood was 26.9% less for the entire village. However, when respondents were asked whether they got sufficient fuel for their cooking and heating needs, 92% felt that there was no scarcity of fuel, 4.7% were of the opinion that fuel availability was less than their actual needs and 3.3% were unable to express their opinion. Thus, it appears that sufficient fuel was available in households for cooking and heating in terms of the total biomass burnt.

The worked-out deficit of 26.9% was met by two sources, animal dung cakes (dry) and crop residues. As the entire village is rainfed, crops are grown only during the monsoon season. Crop residues were largely used as livestock fodder, either green or mixed in concentrate after drying well. Only very small amounts were used as fuel. The calculated value of crop residue used as fuel was 55.1 t/ year or 0.2 t/household/ year. On average, 1.2 t dry animal dung/household/ year or 430.0 t/ year for whole village were used as fuel. The total annual dung (dry) production from the entire livestock population was estimated to be 1578.4 t or 4.4 t/household /year. Thus, the amount of dry dung which is burnt accounted for 27.3% of the total dry dung production. Had the required amount of fuelwood be available to households, this substantial quantity (4.4 t/household/year) of dry dung would have reached the crop fields. Thus, the use of 27.3% of total dry dung production for fuel deprived crop fields contributed nutrient to the soil. Dry dung also increases organic matter, improves soil structure, soil biota and water holding capacity. Although the importance of dung as manure is well recognised in all edapho-climatic situations, its importance is multiplied many folds in structureless, immature and nutrient poor soils of the hot arid zone (Gupta *et al.* 1998).

Towards fuelwood crisis

The wood of two *Prosopis* species, i.e. *P. juliflora* and *P. cineraria* contributed 97.1% of the total fuelwood supply of village Sar. While the former is essentially a part of extra-territorial collection system, the latter comes under private collection system. The private collection system appeared to be very strong up to a quarter century ago, with a reported density of *P. cineraria* on agricultural fields ranging from 5–7 trees/ hectare in extreme western part of arid Rajasthan to 30–40 trees/ hectare in the eastern part, with an average of 20–25 trees/hectare (Shankar 1980). The presence of 20–25 mature trees of *P. cineraria* in agricultural fields gave a production of 0.96–1.2 t dry fuelwood/ ha/ year. This amount of wood production, a quarter century ago, when average land holding size was also relatively large, would have been more than sufficient for the fuel needs of an average size household.

The human population of arid western Rajasthan has increased with much faster rate in the last three decades. In 1971, population density in this part of the country was only 48 persons/ km^2 but increased to 69 persons/ km^2 by 1981, and 89 persons/ km^2 by 1991, and in the year 2000 it was 101 persons/ km^2. The decennial human population growth rate of the arid western Rajasthan in terms of the average of the last two decades was 33.7%, much higher than the 23.5 for India as a whole (Dhir 1995). The total livestock population was 19.13 million in 1977, but in 1997 it was estimated to be 29.6 million, an increase of 154.7% in two decades (Anonymous 1997). This ever increasing human and livestock population has resulted in an unprecedented pressure on vegetation resources in the entire arid western Rajasthan.

The situation of rapidly escalating human and livestock population is also true for village Sar. Until the mid 1970s, the human population of village Sar was around 1600 and that of livestock was around 4000 (Bharati, pers. comm.). Moreover, nomades who always moved with their livestock gradually started settling down around the periphery of village in the late 1970s due to government policies of discouraging nomadism. Such nomades generally settled on revenue lands (often referred to as wastelands), forest department's lands and even on roadsides. As they neither have any land to plough nor any kind of ownership within the village landuse system nor any caste-based profession except for rearing livestock, such settled nomadic population is often not considered part of village, even in census records. However, they frequently use the vegetation resources of revenue lands, government forest lands and many a time even village common (grazing) lands. Thus, along with the rapidly increasing human and livestock population in the last two decades, there is a conflicting situation in the socio-economic and cultural fabric of village society resulting in an unprecedented pressure on woody vegetation resources of the village.

To meet the needs of fuel, fodder and minor timber of such a fast expanding human and livestock population of village Sar, the inhabitants started over-exploiting the superior biomass resources such as excellent multipurpose tree species like *P. cineraria*, *T. undulata*, *A. senegal* and *A. indica* (Hocking 1993) because they were part of private collection system and also due to their easy accessibility. Due to the ruthless exploitation of superior woody vegetation in the last two decades, *T. undulata*, also known as desert teak, is today on the verge of extinction. However, before a quarter century ago, villagers used to exploit these superior tree resources through perfectly managed annual lopping or sometimes polarding for their fuel, fodder, minor timber requirements and as such the sustainability of production from these superior tree resources remained maintained for years (Shankarnarayan 1984). Anecdotal evidence suggested the nomades who started settling down with their livestock around the village, first targeted mature and straight stem trees of *P. juliflora* growing on revenue and forest lands as well as on roadsides because these lands were out of the jurisdiction of village local self governing body. Moreover, when rapidly depleting densities of superior biomass sources available on agricultural fields of villages reached an alarming state, the attention of villagers shifted towards *P. juliflora* thickets, the only other available source, though inferior as far as the multipurpose nature of the species is concerned, for their fuelwood needs and to some extent for their livestock feed. *Prosopis juliflora* pods are available nine months in a year, from September till May, and are very nutritious and highly palatable.

Thus today, *P. juliflora* is providing more than 68% of fuelwood to inhabitants of village Sar. However, this resource is being exploited ruthlessly. As the species is a vigorous coloniser and excellent coppicer, it now occurs only in the form of dense bushy thickets because plants of this species are never allowed to grow without any disturbance (Tewari *et al.* 2000).

In general, the fuelwood resources of village Sar are being depleted rapidly. From private collection only 31.4% of demand for fuelwood is being met at present, with 68.6% coming from extra-territorial sources, i.e. from the dense coppice growth of *P. juliflora* on revenue lands, forest lands and roadsides. Due to over-exploitation of *P. juliflora* in the form of repeated cuttings of even very young shoots, a situation has arrived that growing stock of *P. juliflora* has also been degraded to a considerable extent and only coppice shoots of 1.4 to 4.3 cm diameter are available in the bushy thickets of the species. In terms of biomass, 1.21 t/ household/ year dry animal dung was being burnt to fill the gap of fuelwood supply. Thus, the current situation suggests that village Sar is gradually entering a transition in which fuelwood depletion is going to be fuelwood scarcity in the very near future, which will ultimately lead to a fuelwood crisis in the village. Moreover, uncontrolled collection of fuelwood, particularly from government controlled revenue lands and forest lands, provides a catalyst for environmental degradation in the form of soil erosion and habitat loss for arboreal and ground-dwelling wildlife (Braysher 1983).

Future trends and fuelwood management options

At present, domestic cooking in village Sar is based entirely on fuelwood, animal dung cakes and crop residues (73.1, 23.8 and 3.1% respectively). Due to an ever increasing population (both human and livestock) and associated needs, the demand of fuelwood is bound to increase in future. The superior sources of fuelwood (i.e. private collection system) have already been exhausted or deteriorated to an alarming state. The inferior sources of the extra-territorial collection system are now not in a position to supply sufficient fuelwood due to their ruthless exploitation in the past and consequent degradation.

Use of cattle dung for energy purpose depends on the level of use of fuelwood and with the decrease in fuelwood consumption, the share of dung cakes in domestic fuel increases (Borah & Goswami 1997). Because crop residues are commonly used as livestock fodder in village Sar, there is no chance that villagers could transfer these resources to use as fuel. In this scenario, dry dung is the only alternative to fill the gap between demand and supply of fuelwood. If the current rate of depletion or degradation of *P. juliflora* thickets (which presently accounts for > 68% of the total fuelwood supply) continues, within the next four to five years, the deficit of fuelwood supply, which is at present 26.9% will reach 50%. In such a case, 53.7% of the total dry dung production will be diverted to fire places of village households. This in turn will further deprive the agricultural fields from such a vital soil fertility enhancing input.

To regulate the fuelwood supply as per need of villagers, it should be very clear to the concerned state government agencies like revenue department, forest department and district rural development agencies that the rights which comprise tree tenure are as complex as, and quite separate from, the rights that comprise land tenure (Fortmann 1993). Over the last few years, USD400 million were spent to establish social forestry programmes but with very little success because of the lack of legal mechanisms to ensure secure tenure, undermined attempts to involve communities in rehabilitating much of the degraded forest lands and fellow revenue lands (Poffenberger 1993, Tewari *et al.* 2000). The best option for managing revenue lands (often referred to as wastelands), forest lands and village common lands in hot arid regions, which support only degraded woody vegetation, mainly *P. juliflora*, should be that they are brought under community participation, which is the key factor for long-term success of local resource management (Korten 1986).

Prosopis juliflora was first introduced in India 130 years ago (and was given the status of royal tree in Jodhpur in the 1940s) and with the passage of time due to its wide ecological amplitude, it has spread in the entire arid and semi-arid tropics, which accounts for 40% of the country's total land surface. Today, the species is proclaimed as disaster in many quarters due to its rapidly colonising ability and the presence of thorns. The state government of Rajasthan even started an eradication programme without any consideration of alternatives, when the species is the source of more than 70% of the fuelwood supply in rural areas of arid western region (Faroda & Singh 1998). *Prosopis juliflora* when protected often forms good woodlands and it forms bushy thickets only due to its over exploitation in the first two to three years of growth (Tewari *et al.* 2000). Therefore, the eradication programme of the species is not going to serve any purpose and rather it may be counter productive because in the absence of any alternatives, the pressure will further increase on already depleted superior tree species resources.

The abundant bushy thickets of *P. juliflora* should be observed as a valuable natural resource, not as a disaster. Better community participation and simultaneous use of improved silvicultural techniques, and soil conservation and water harvesting measures may help to improve the *P. juliflora* stands. The species has immense potential and could be utilised with profitability in the rural forestry sectors of the entire hot arid zone of India (Pasiecznik *et al.* 2001, Tewari *et al.* 2001).

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