

22 July 2000

Dear Niranjani

Thank you for sending me those papers.
I am currently pursuing a Ph D on
the Economic Analysis of Protected Areas.

Can I request you to please go through
this ^{very initial} draft of a paper that I have
written on "fuelwood, land and conservation"?

I will be pursuing this topic in greater
detail in the context of Ranthambore
National Park. I will be grateful
for your criticisms and suggestions
for possibly possible future lines
of enquiry.

Thank you.

Vibram Dagal

TERI

My email addresses:

vikday@ieg.ernet.in

vikday@teri.res.in

Fuelwood, land and conservation

A first draft exploring ideas

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Introduction

The fuelwood issue has generated considerable interest and scrutiny over the years. Observations that women and children were spending many hours gathering fuelwood in some locations, fears that people were moving down the energy ladder, and perceptions that fuelwood was a great pressure on forests, motivated scholars to examine the issue. However, some felt that the 'crisis' had been overblown—people successfully averted fuelwood problems by responding in a variety of ways. Often, rural people had more pressing concerns than fuelwood. Nor was fuelwood a primary cause of the degradation of forests, piling in comparison with the demand for land for agriculture, and the effect of commercial forestry.

This paper explores the links between fuelwood, land use and biodiversity. Specifically, the links between the following categories are explored.

- Society/economy: including incomes, cooking practices
- Land: including different land-uses, and location
- Energy: including different traditional and commercial fuels
- Ecology/biodiversity: including richness and diversity of biomass, its productivity, and contiguity of land.

The links are explored through heuristic analytical arguments and empirical observations, by drawing on, and interpreting, a number of studies.

The danger with trying to 'link' too many things is diffusion. However, one theme runs through the observations in this paper—proximity to open access resources by villagers with low opportunity costs of time overwhelms other supply and demand responses. The landscape consists of urban and rural centres of demand, roads, open access and other sources of fuelwood, at different *locations*. The landscape changes with *time*.

Fuelwood in India today

It is useful to look at the issues of firewood and land in the present context in India. One reason that the firewood issue has been a bit of a mystery is that there are few studies which capture its evolution over time. In a thought-provoking piece titled False predictions, Agarwal (1998) interpreted the findings of a survey by the National Council of Applied Economic Research (NCAER) (Natarajan 1995). This survey provides some insight into the evolution of the fuelwood issue from 1978/79 to 1992/93.

Table 1. Rural household energy consumption in India: 1978/79 and 1992/93

Fuels	1978/79		1992/93	
	Quantity consumed (million tonnes of coal replacement)	Share of fuel in total consumption (%)	Quantity consumed (million tonnes of coal replacement)	Share of fuel in total consumption (%)
Coal/soft coke	1.7	1.9	0.6	0.4
Kerosene	2.3	2.6	6.8	4.4
Cowdung	20.1	22.5	26.2	17.0
Crop residues	15.5	17.4	20.5	13.4
Firewood logs	16.9	19.0	50.0	32.5
Firewood twigs	31.8	35.6	44.8	29.1
Others	0.9	1.0	5.0	3.2
Total	89.2	100.0	153.8	100.0

Source. Natarajan 1995

Agarwal notes that there is one dominant finding of the survey (Table 1)—the huge increase in the total quantity and share of firewood logs. The total quantity of firewood logs in rural areas went up from about 17 million tonnes of coal replacement (mtr) in 1978/79 to 50 mtr in 1992/93. The share of fuelwood logs went up from

19% in 1978/79 to 32% in 1992/93. Whereas firewood twigs, cowdung and crop residue consumption went up in terms of quantity, they all went down in terms of share of total consumption. Interestingly, the share of households which used crop waste stayed almost the same, while those using dry dung actually increased marginally from 59% to 63% (Natarajan 1995). This may appear to contradict the earlier statement but the reason is that when we add up the percentages of households using different fuels we get more than 100%—households often use more than one fuel. Agarwal stresses that there was a movement up the energy ladder from twigs to logs. However, we observe that while this is clearly indicated by the survey, in some locations there could have been a slight movement down the energy ladder to dung.

The NCAER survey showed that the percentage of households collecting firewood from forests had halved between 1978/79 and 1992/93 whereas the percentage of households collecting firewood from their own farms had gone up from about one-third to one-half. Agarwal also draws on other studies which help explain how the increased firewood consumption was supplied. Eucalyptus-based farm forestry in the agricultural plains and the invasion of *Prosopis juliflora* (mesquite) in public lands in dry regions in India, possibly played a large role. *Prosopis juliflora* provides as much as 32 dry tonnes of biomass per hectare.

How were the forests affected by this? In 1978/79 35% of households were collecting firewood from forests, and in 1992/93 this number had fallen to 17% (Natarajan 1995). Agarwal stresses that people respond to degradation and their response left the forests untouched. Clearly, there is a point of significance here. But we pose the question: could it also be that the degradation of forests encouraged those responses? Were forests affected in spite of the great increase in the farm as a source of wood—from 35% in 1978/79 to 48% in 1992/93 (Natarajan 1995)?

Table 2. Rough estimate of fuelwood log consumption from forests (million tonnes of coal replacement): 1978/79 and 1992/93

[assuming fuelwood log/twig consumption from forests = total fuelwood log/twig consumption × proportion of households which are extracting fuelwood logs from forests]

	1978/79	1992/93
Fuelwood logs	5.9	5.5
Fuelwood twigs	11.1	4.9

Source. Estimated from Natarajan (1995)

Rough estimates made from the survey (Table 2) indicate that the consumption of fuelwood logs from forests fell only marginally between 1978/79 and 1992/93, whereas the consumption of fuelwood twigs from forests more than halved. To answer the question of the effect on forests, we need to know the following:

- the *location* of consumption and extraction. The numbers so far are at too aggregated a level.
- the effects of twig extraction on forest regeneration, at different stages. While twig extraction is clearly less harmful than log extraction, could it be that twig extraction under some circumstances may even be beneficial?

Having posed these questions, we enquire into the choices that households make with respect to fuelwood.

Households and fuelwood

Responses to abundance and scarcity

Dewees (1989) has argued that households change their behaviour when faced with abundant or scarce fuelwood. There is a range of mechanisms available to a household. Some of these have received considerable attention. For instance, households can change their cooking and heating habits to adjust to changes in fuel availability.

Another adaptation which has received considerable attention is moving up or down the energy ladder. Households will substitute fuels so that they get the most 'convenience energy' per unit cost, subject to availability. I use the term convenience energy to incorporate both the calorific content of fuels and its convenience to the user. The convenience is dependent on cooking practices and habits, and is culturally and historically determined, varying geographically and across income classes. Fuelwood is often preferred by rural people. However, for the preparation of ghee, cowdung may be preferred by some villagers because it is suitable for providing a slow fire. In urban areas people with higher incomes move up the energy ladder, opting for LPG and kerosene if available. A considerable proportion of the urban population in developing countries does purchase fuelwood.

Often, insufficient attention is given to people's motivation when designing programmes. For instance, in a study carried out in villages in Madhya Pradesh, the 66 portable chulhas installed were found to be used only occasionally primarily because people had access to the dense forest nearby (see Malhotra, Dutta and Ramana 1998, p. 11). Possibly, plantation measures could also not be attractive to people so long as they are close to forests or even protected areas, as long as there is *effectively* a situation of open access.

Opportunity costs of time

As Bluffstone (1995) observes, the relationship between fuelwood dynamics and labour markets in rural areas has not received much systematic attention. Bluffstone has built a formal model of subsistence agroforestry in the hills of Nepal. A

household derives utility from the consumption of food which depends on grain and fuel. It faces income and time constraints. It can sell milk or labour, and purchase grain and fuel (only kerosene can be purchased). It can either put in labour time in off-farm work, fuelwood gathering, grain production or milk production.

Bluffstone thus establishes a link between off farm-labour and fuelwood gathering.

If gathering, then

$$w/p_e < \partial e/\partial t_e$$

w: wage rate, opportunity cost of time

p_e : price at which energy is being purchased

e: energy gathered

t_e : time spent in gathering energy

in other words,

kg of energy from working one hour < kg of energy from gathering for one hour

Women and children usually collect fuelwood for the kitchen at home, and so it is their opportunity costs of time which would matter in the decision to gather or not gather energy. Men often take decisions with respect to purchasing energy, so perhaps it is the perception by men of the opportunity costs of the time spent by women which often matters (see Malhotra, Dutta and Ramana 1998).

As we shall see, fuelwood gathering is common in a lot of protected areas, and often, there is gathering for sale too. Protected areas are also more likely to be in places not suitable for agriculture. The opportunity cost of land is low, and alternative land uses are not as attractive as in other locations. On the other hand, it is likely that in such locations the opportunity cost of labour is low, thus increasing the probability of fuelwood gathering.

In the Bluffstone model the possibility of fuelwood purchase is not taken into account, nor is the possibility of gathering fuelwood for selling elsewhere. Only kerosene is bought or sold in the Bluffstone model.

If we consider the possibility of fuelwood gathering and sale by villagers, then they will gather fuelwood and sell if:

$$w < \partial e/\partial t_e \times p_e$$

Rs from working one hour < Rs from gathering for an hour and selling

Spatial aspects of fuelwood

Fuelwood is a renewable resource and its extraction over and above regeneration will result in lowering the stock and increasing the cost of extraction. Bluffstone links the two thus:

Time take in gathering in at time point $t=B(\text{Stock at time } t)^{-\psi}$

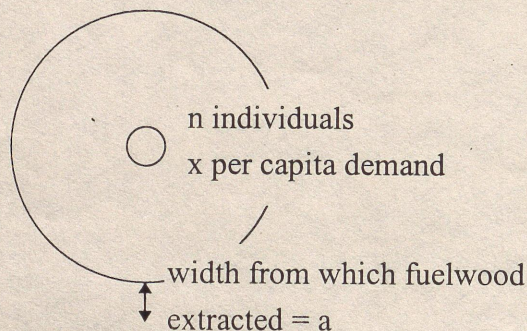
$0 < \psi < \infty$

Bluffstone has three good reasons for choosing to formulate it in this way, and we will not mention them. However, for the argument being developed in this paper, it is critical to make the link between fuelwood extraction and the spatial aspect of the resource stock. The following is an intuitive attempt at capturing this link. It is somewhat unsatisfactory, and perhaps can be improved.

$\partial e / \partial t_e$ will depend on distance from stock, S

As S falls, $\partial e / \partial t_e$ will also fall, i.e. less kg per hour.

Intuitively, if we think of a circle with its circumference representing the boundary of stock, and centre demand:



If $nx > \Pi [(r + a)^2 - r^2]b$ then stock gets pushed out, r increases, costs of gathering increase, i.e. $\partial e / \partial t_e$ decreases.

Fuelwood in rural areas

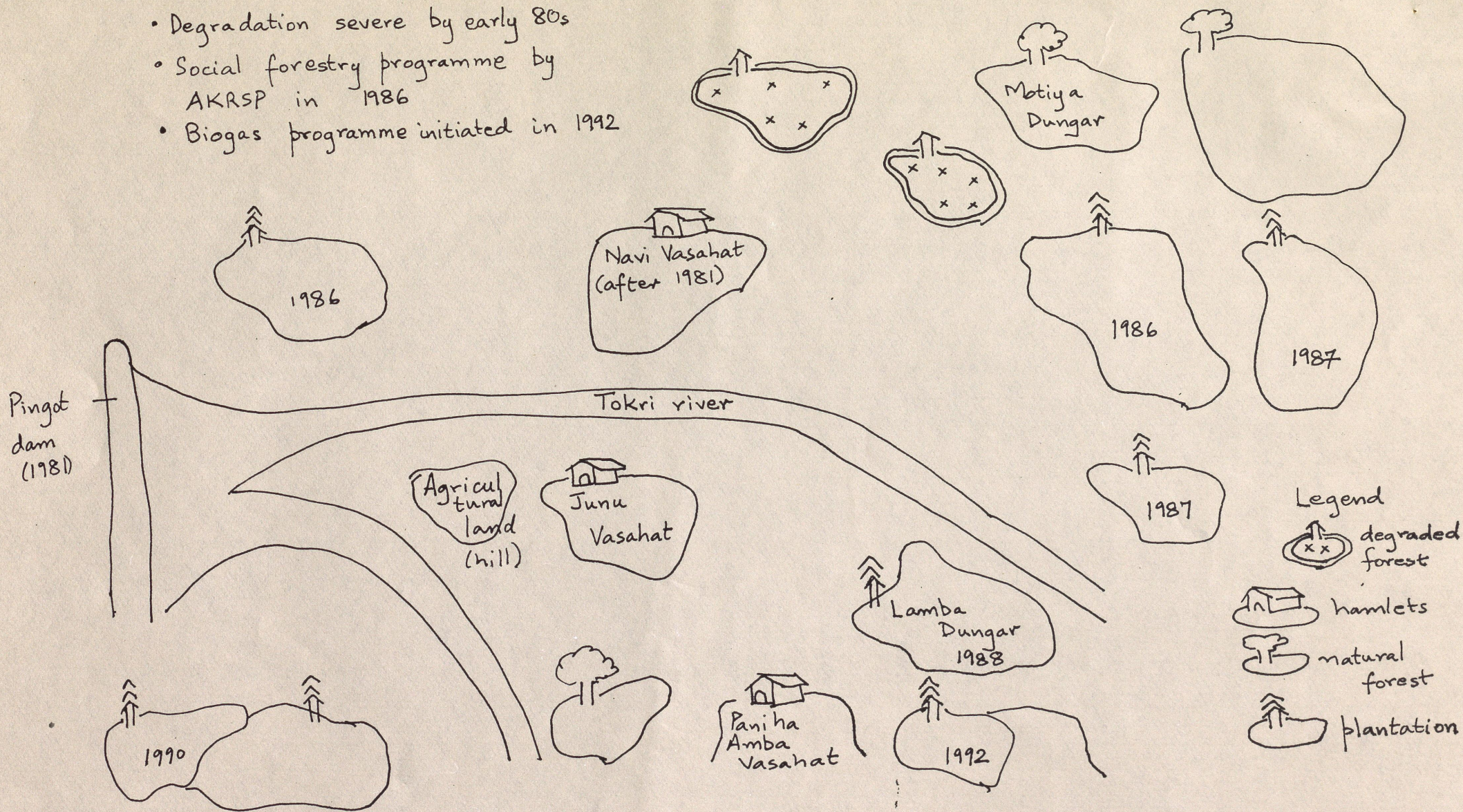
A map of the rural energy landscape

What does the rural landscape actually look like? Techniques using participatory rural appraisal have mapped village resources. We present one such study (TERI 1995) carried out in Pingot, a tribal village in the state of Gujarat, which helps us visualise the interactions between energy consumption, wood extraction and the rural landscape.

The original Pingot village comprised the Paniha Amba and Juni Vasahat hamlets. After the construction of the Pingot dam in 1981, many families migrated to the northern part of the village across the Tokri river and thus the Navi Vasahat hamlet came up (see Figure 1).

The Paniha Amba and Juni Vasahat hamlets are surrounded by hills which earlier had luxurious forests of Teak and Khair. However, in the early eighties, this had

- Degradation severe by early 80s
- Social forestry programme by AKRSP in 1986
- Biogas programme initiated in 1992



Legend

- ⓧ degraded forest
- 🏠 hamlets
- 🌳 natural forest
- 🌲 plantation

Figure 1 Map of Pingot village

become a virtual wasteland due to a continuous outflow of fodder and fuelwood. From 1986 onwards, most of these degraded forests have been protected or afforested and conserved by the villagers.

All households in Pingot use a fuel mix of wood, dungcake and crop residue, though wood is the preferred fuel. Besides meeting the cooking requirements, biomass fuels are also used for water and space heating in winter and monsoon seasons.

Though women are primarily responsible for the collection of fuelwood, men are also actively involved. Headloading is usual, though a few families have bullock carts to transport wood. Bullock carts for transporting wood are hired at Rs 35 per trip and each cart can carry 200 kilograms of wet wood or 300 kilograms of dry wood. About 9% of the households in the village employ labourers to fetch wood from the forest at Rs 15 per day.

71% of the households use wood cut from the degraded forests in the vicinity of the village. A few families (11%) in Junu Vasahat use dry twigs and branches collected from the protected joint forest management area. A large number (18%) of the households gather wood from the field bunds of their personal agricultural land. Each of the three hamlets in the village access different forest sources for collection of wood and the distances involved are:

Navi Vasahat – Motiya Dungar hill and other unprotected natural forests (3 km)

Junu Vasahat – Lamba Dungar hill forest (2 km)

Paniha Amba Vasahat – Rajwadi village forest (2 km)

A social forestry programme was initiated by AKRSP at Pingot village in 1986. Over the next seven years, the villagers afforested 229 ha of forest land, 64 ha of revenue land, and protected another 50 ha of land belonging to the forest department. Through a process of strict social fencing success was achieved in this effort.

An interdependent biomass system

The village economy is an interdependent biomass system. A TERI (1994) study gives us some key insights on the biomass system in some villages in the Irgad micro-watershed in Pauri Garhwal district of Uttar Pradesh. One of the key insights of the study was the distinction between the biomass system and the village boundary. People have access to biomass outside the village boundary if they enjoy rights and concessions on other land categories, purchase biomass resources or obtain the resources illegally. In 9 of the 24 villages studied, the biosystem area differed from the village area by more than 10%.

The study estimated the stress on biomass resources by estimating the ratio of demand to supply (supply for wood, for instance was increment from trees in the biosystem). Of the 24 villages that were studied, 9 faced stress in manure, 17 faced stress in grass, 16 faced stress in shrubs (source of woody biomass), and 10 faced stress in trees in 1992. Over time, these stresses are likely to increase because of a

growing population. Of course, these stresses may be successfully overcome.

Woody biomass came from a number of sources: homesteads, commonland, and agricultural land. There were wide variations in the percentage distributions of woody biomass from different types of land across villages. In village Kandai Malli, 98% of woody biomass was extracted from agricultural land, whereas in village Jairaj agricultural land accounted for a mere 20% of woody biomass. In several villages, homesteads were very productive: in the village Agrora, for instance, 17 percent of the biomass was grown on homesteads, which occupied a mere 1.5% of the total land in the village.

Fuelwood to urban areas

Fuelwood demand from urban areas can have a large impact on the rural landscape. Hofstad (1997) has modelled how the circle of deforestation due to charcoal supply will spread from Dar Es Salaam. We have illustrated the Hofstad argument, based on our understanding of his paper. Dar es Salaam is on the Indian Ocean, and a highway runs westward from it towards Morogoro. Along the highway there are dirt roads which run south and north on the highway. In Figure 2 the westward distance is represented by d_1 and the north south distance by d_2 .

Essentially, transport costs will determine the size of the exploited wedge. Transport costs increase with distance d_2 , and with distance d_1 , but since d_2 represents rougher road conditions, the transport costs are higher per unit distance along d_2 . As demand increases, price goes up and the wedge expands.

A changing landscape

We have seen that the village is a mosaic of different lands: private agricultural land, homesteads, commonland consisting of plantations and forests etc. Also, urban demand for fuelwood can play a big role, along with rural demand, in changing the interdependent biomass system that a village is. But what shapes land use?

We draw on a simple model by Hyde, Amacher and Magrath, with a slightly different interpretation and emphasis. Figure 3 represents the von Thunen diagram of land use. Till point A, the land has highest value when used for agriculture. From A to B, land will be used for forest products. What if the demand for forest products, and its price, goes up? Then land use will adjust to meet this demand. If fuelwood extraction over time reduces its availability from land which is open access, villagers will plant trees on their own fields. Firstly, and this is pointed out by Hyde, Amacher and Magrath, the open access area will have to be less rich in biomass before villagers have an incentive to plant trees. Secondly, they must have some tree security—either

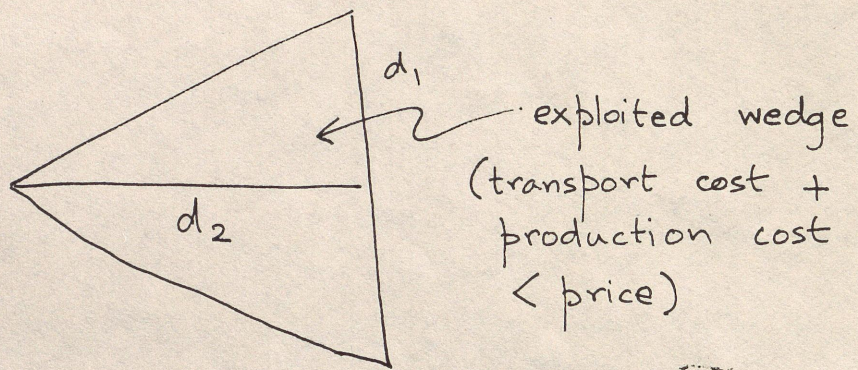
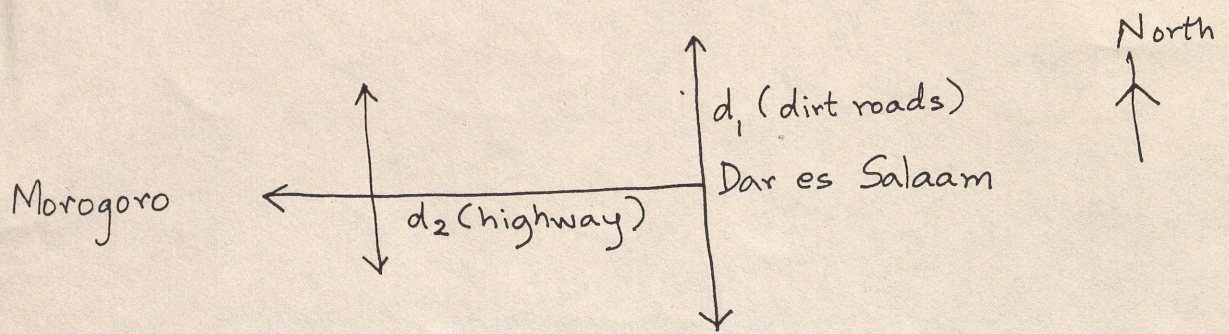


Figure 2. Expanding wedge of deforestation from Dar es Salaam

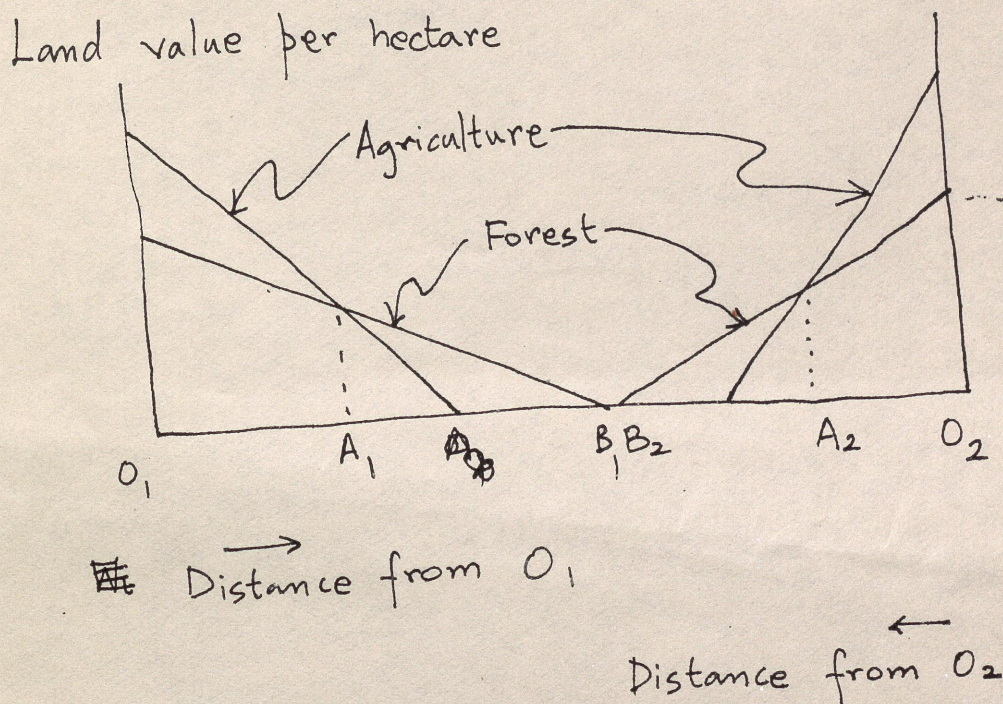
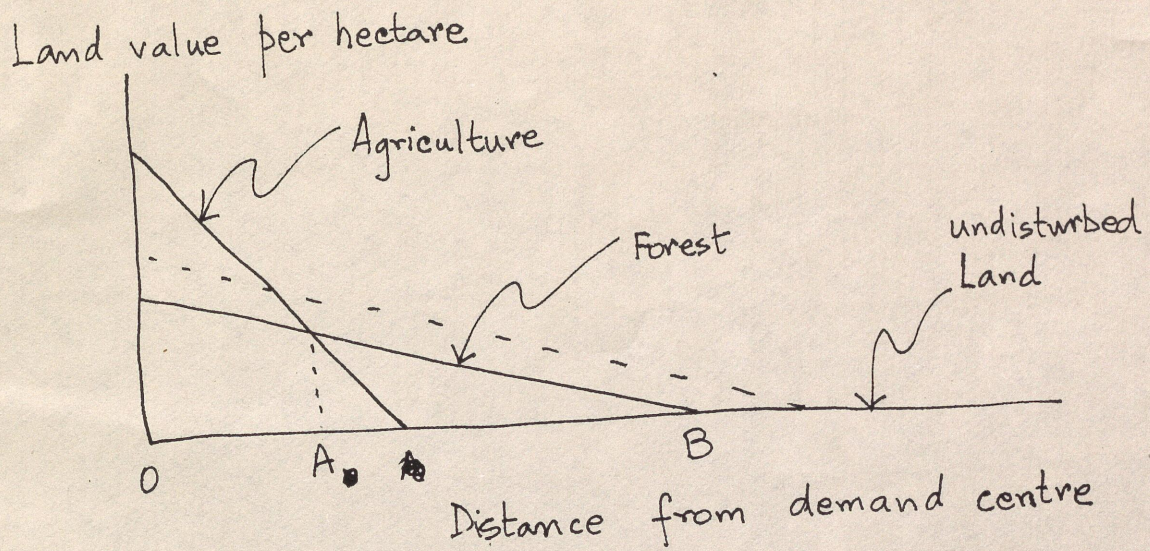


Figure 3 Shrinking area for undisturbed land as demand centres grow

owning land or being able to plant trees and being reasonably assured of lack of theft etc. But one can make a deeper point with respect to biodiversity.

Imagine not one but two demand centres. We see that the values of land for forest products will rise and adjust vis-a-vis the agricultural land. But what happens to the frontier of undisturbed land, which in the final analysis is a vital repository of biodiversity? It is likely to be lost, especially because the values it generates do not enter the signals of the market. By designating protected areas in developing countries, an attempt has been made to maintain a frontier of undisturbed land. But it is, in a sense, counter to important economic forces.

Fuelwood in protected areas

Stylized fuelwood behaviour in protected areas

We now put the insights all this together to consider the landscape around a national park. Consider Figure 4. We have a core area of the national park, which is rich in biomass, a buffer area and surrounding area. Generally the buffer area will not be as rich in biomass as the core area, and the surrounding area will be less rich in biomass compared to the buffer area. Consider three stylized villages, A, B and C. Village A is within the protected area, village B is very close to the protected area and village C is at some distance.

Then consider

- agricultural possibilities
- fuelwood gathering for self
- fuelwood gathering for sale.

In the case of village A, agricultural possibilities are likely to be very limited. The village will have access to a lot of fuelwood, and the costs of gathering will be very low. Fuelwood gathering for sale is also likely, especially if the village is not too much in the protected area, the terrain is easily traversible, a road is not too far, and there are urban or rural centres of demand.

In the case of village B, agricultural possibilities are not limited, at least not by land availability, but more by the usual kinds of limitations to agriculture (including climate, soil, irrigation etc.) Fuelwood gathering is again easy, constrained primarily by the attitude of the keepers of the forest, and there is always the option of gathering for sale.

Finally consider village C. This is a threshold village. The village is indifferent to extracting resources from the protected area and growing its own fuelwood on a plantation (this makes it more interesting than if an alternative non-protected area open access source were available to it). We may state the equality thus:

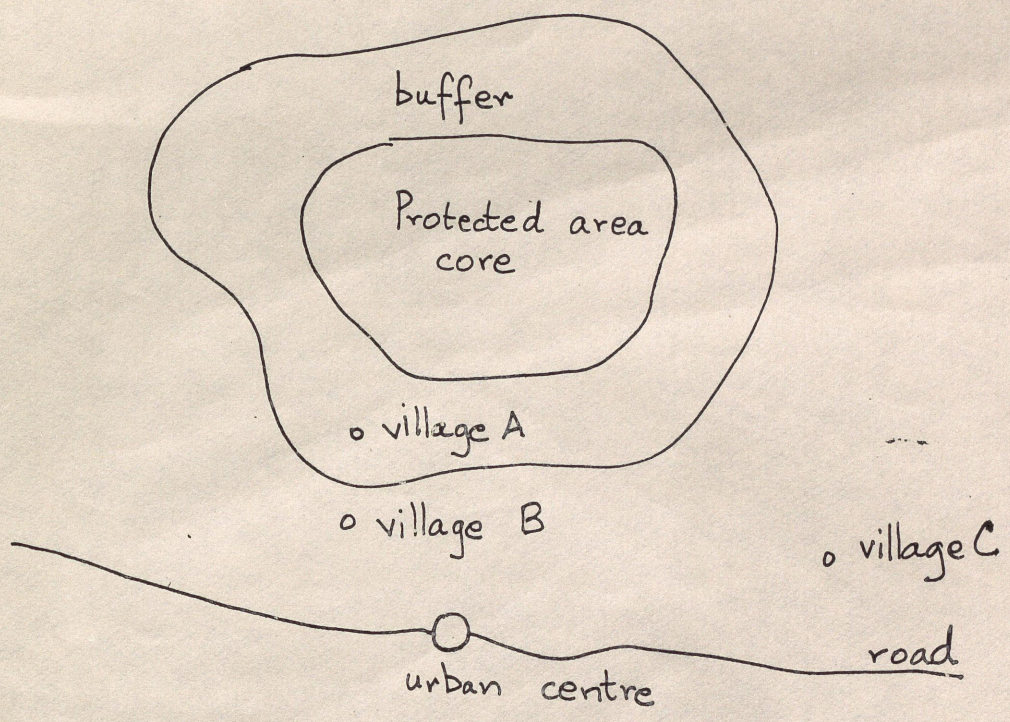


Figure 4 Stylized villages and protected area

Ecological uncertainty

Finally, we consider some gaps in our understanding of the ecology of fuelwood removal. Firstly, how well do we know what the effects of fuelwood removal in general are? How are the mean annual increment numbers estimated? Could light levels of fuelwood lopping, removal of fallen branches, actually increase biomass productivity.

An educated guess would be that at low levels of extraction, there may be no significant damage, and after a threshold the damage is cumulative. If the levels of extraction are such that it is clear that the biomass is going to be substantially reduced in particularly areas i.e. it is clearly going to be thinned, then what would be the impact? One quantitative way would be to use the species area relationship, say that thinning effectively reduces the protected area, and then make an estimate of reduced effective protected area. It is not likely that any ecologist would be happy with this.

fuelwood But another question has perhaps not been explored. And that is the cumulative effects of ~~livestock~~ and fodder. Livestock grazing in semi-arid rangelands can change the composition of the biomass covering the ground from grasses to woody shrub. But what if fuelwood is also being extracted? In the presence of grazing, regeneration of trees is adversely affected. Hence, an exotic like *Prosopis juliflora*, which has been grown in plantations, and is productive, has according to N C Saksena, solved the fuelwood problem in several areas in India. Another instance of the tradeoff between fuelwood and biodiversity?

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Time costs of gathering from plantation + costs of growing plantation = costs of gathering from protected area + costs of forest guard encounter. The ring of all such villages C represents the border of villages dependent on the protected area for fuelwood. It may be possible that substitution by dung or agricultural residues is cheaper than the growing of a plantation, but at this stage let us ignore this possibility.

Case studies of fuelwood in protected areas

Shankar, Hegde and Bawa (1998) studied the extraction of fuelwood from the Biligiri Rangan Hills, in the state of Karnataka in India. The sanctuary is inhabited by people belonging to the Soliga tribe, and non-Soligas. These people living in the sanctuary legally inhabit settlements within the sanctuary. They depend on forest wood. People on the fringe of the sanctuary also illegally cut fuelwood from the forest. The authors estimated that the demand for forest wood for fuel use from the sanctuary was 49,165 tonnes per year, less than the net wood production from the sanctuary as a whole. However, since the same patches (about 20% of the total area) are visited by those extracting fuelwood, the effective wood growth would amount to 13271 tonnes per year. As a result, there are likely to be patches around the settlements within the sanctuary, and on the boundary, where the biomass will be thinned.

Similarly, in the Rajaji National Park in the state of Uttar Pradesh, areas close to the boundary of the park were affected by firewood cutting. It was found that all areas affected by grazing are also affected by firewood collection, though in four ranges firewood collectors penetrate further than herders. The depth of the affected area ranged up to a maximum of 5 km from the park boundary. (Berkmuller 1986 cited in Dang 1991).

In the Binsar Wildlife Sanctuary in Uttar Pradesh, 115 households reside in 7 villages in the sanctuary (Bathla and Perwaiz 1999). A survey found that on average, for each household, 27% of the income came from selling fuelwood and 44% of the income came from selling fodder, collected from the sanctuary. Once again, the extraction of firewood may lead to a great loss of growing stock.

The Ranthambore National Park in Rajasthan covers a total area of 392 square km, out of which 274 square km is core and the rest is buffer. Since the buffer is degraded villagers often cross over to the core to cut wood. The Forest Department was reported by Desai and co-authors (1996) as issuing 80–100 permits for collecting headloads for a period of 15 days. However, the actual number of headloaders far exceeded this number.

Khan found that the townships around the Ranthambore National Park were major consumers of fuelwood. The tree species Dhok (*Anogeissus Pendula*) met up to 90% of the requirements of human and livestock populations ranging from firewood to timber, fodder, thorny bush etc. A study of biomass density conducted by Khan revealed that both tree density and grass cover in the buffer was low.

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