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Livelihood Transformability in Indian Villages with Poor Water Resources: The Case of Tamil Nadu

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1. Introduction

Since the beginning of the 1980s, the Indian economy has maintained a growth rate of approximately 6% per annum (Yanagisawa 2008). This is well-known to have been based on agricultural development since the mid-1960s, termed the “Green Revolution,” through which rice and wheat yields per unit of land have increased dramatically. Rice and wheat varieties released mid-60s required adequate irrigation facilities, which were promoted by the government during this period (Esho 2008; Sivasubramaniyan 2006). One state that enjoyed particular success during the Green Revolution was Tamil Nadu. It was proudly described by the Government of Tamil Nadu (GOTN) as having “been transformed from a food-deficit to a surplus State in a short period. The achievement has been made possible by the agricultural strategy adopted” by state government. (1972: 15).

Such an ideal combination of irrigation, agricultural growth, and poverty reduction is unlikely to be available during the next phase, when agricultural growth must increasingly derive from less-favorable regions with limited water resources (Shah 2001). Water shortages threaten agricultural livelihoods and agricultural wage laborers throughout India. Seasonal movement of the labor force from water-scarce regions to irrigated and economically developed regions has been a common survival strategy; however, long-term or permanent out-migration has also been increasing (e.g., Shah 2009; Sundari 2005; Venot et al. 2010).

The Gundar River Basin located in the southern part of Madurai is a typical example of this situation. It is known as a monsoon shadow area, in which peak rainfall is observed not in the wetter southwest monsoon season (June–September) but in the dryer northwest monsoon season (October–December). To use the limited rainfall effectively, tank irrigation systems have been developed from time immemorial (Palanisami 2000). However, disparity in irrigation water access between the upper and lower river basin greatly accelerated from when well irrigation in the upper river basin expanded rapidly after the 1990s. While farmers in the upper the basin intensified and diversified their cropping successfully, those in the lower basin have failed to introduce cash crops (Sato and Periyar Ramasamy 2011). Consequently, large amounts of arable land have been abandoned. Such changes in land use have supported the widespread invasion of a particular tree species: *Prosopis juliflora* (Swartz) D.C. (Sato and Periyar Ramasamy 2011; Sato 2013).

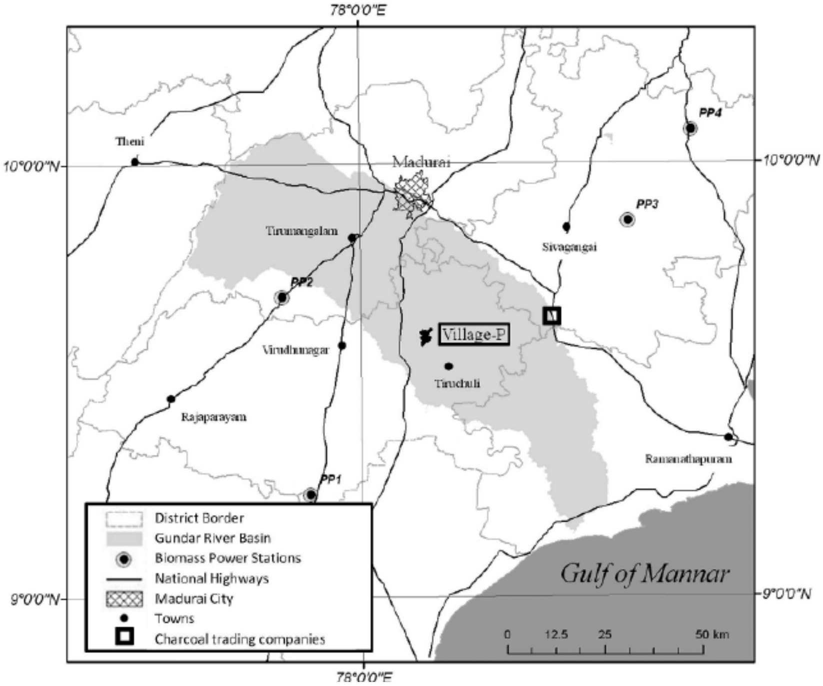
"Transformability" denotes the capacity to create a fundamentally new system when ecological, social, and political conditions make an existing system untenable (Walker and Salt 2006). This study examines the transformation of rural livelihood in a village of rapidly declining agricultural production, based on previous studies (Sato and Periyar Ramasamy 2011; Sato 2013) and recent surveys. The factors enabling transformation of the villagers' livelihood were investigated. The paper first presents the process of agricultural decline in the selected village, using government statistics, the results of a survey conducted in 2011, and satellite image analysis. It then describes the mode of securing livelihoods following the agricultural decline, before presenting the study's conclusions and practical implications.

2. Materials and Methods

2.1 Study Site

Tamil Nadu has 17 major river basins, one of which is the Gundar River Basin. The study village of Perunjaripudupatti (Village P), located in the middle of the basin, belongs to Virudhunagar district (Figure 1). It is also located about 30 km south of Madurai, the third largest city in Tamil Nadu. With no bus running directly from Village P to Madurai, the journey takes almost two hours. The village's total geographical area is 767 ha, 71% of which (545 ha) is registered as agricultural land. Two tributaries of the Gundar River (the Thekkar and Goundanathi Rivers) meet at this village, although they are both seasonal. An irrigation tank used to irrigate the *nanjai* ("irrigated land" in Tamil) is located in the northern part of the village. The registered area of *nanjai* was 98.5 ha. This tank is connected to the upper part of Thekkar River, and river water flow and runoff water from the catchment area are stored in it, especially during the north-east monsoon season. The circled numbers in Figure 1(b) represent the locations of the sluices (tank water outlets). The level of sluice is lowest in sluice No. 1 and rises from west to east. In other words, the amount of irrigation water provided from the tank is greatest for sluice no. 1 and lowest for sluice no. 4. The *punjai* ("dry land" in Tamil) extends widely on the southern sides of the rivers; its total size is 446.5 ha. Figure 2 presents the rainfall characteristics of Aruppukottai town, which is located about 11 km south-west of Village P. The average annual rainfall during the agricultural seasons from 1993/94 to 2005/06 was 765.8 mm. According to Solaimalai *et al*. (2014), only one drought occurred during this period: a moderate drought in 2002/03.

(a) Location of village P



(b) Map of village P

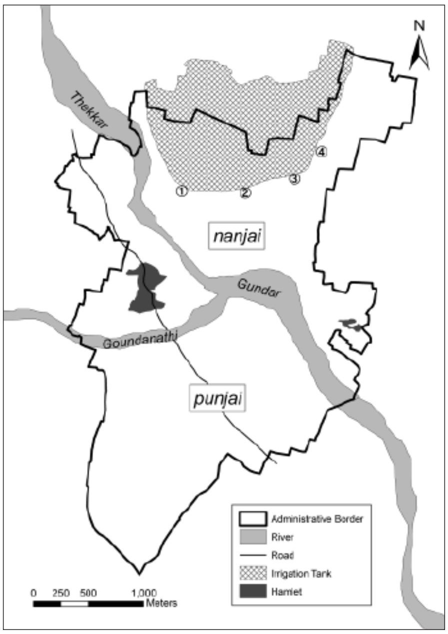


Figure 1 Map of study area

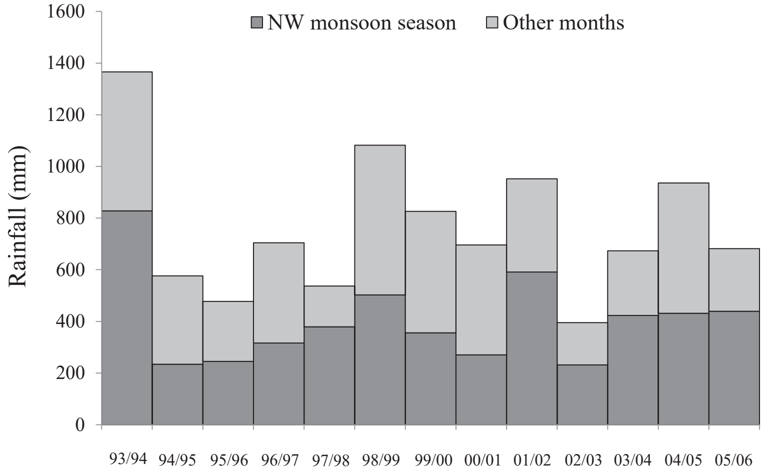


Figure 2 Annual rainfall from 1993/94 to 2005/06 agricultural seasons
Data source: Virudhunagar district statistical office

2.2 Agricultural Land Use and Prosopis Area Coverage

Data on the crop-wise cultivation area in Village P was sourced from Tiruchuli taluk office for the 1993/94, 1995/96, 1996/97, 1997/98, 1999/00, 2000/01, 2001/02, 2004/05, and 2005/06 agricultural seasons. The Prosopis land coverage in Village P in 2002 and 2009 was estimated using the supervised classification method, employing two multispectral satellite images captured by IKONOS (Spaceimaging Inc., USA) on May 13, 2002 and by QuickBird (DigitalGlobe Inc., USA) on May 5, 2009 (Sato 2013).

2.3 Village Survey and Estimation of Agricultural Income and Prosopis-related Income

We conducted a survey of 234 households in Village P in 2011.[1)] On-farm income of the farming households was estimated as follows: first, production amount of each crops in 2000, 2005 and 2010 were collected. They were multiplied by harvest prices of the corresponding years, which were obtained and estimated from government statistical records (Government of Tamil Nadu (GOTN) 2002; 2007), to obtain the gross income from each crop. Then, the crop-wise gross margin, as estimated from a production cost survey conducted in 2008 (rice, 40%; millet, 50%; cotton, 40%; pulses, 45%; oil crops, 30%; and fruits, 40%), was multiplied by gross income, although the gross margin ratio might differ from year to year. Besides the income from crop production, a landholder whose land was covered by Prosopis received a logging permit fee from a Prosopis collector, and the price of which depends on the volume harvested. Information related to the logging permit fee and, approximate dates of Prosopis clearance during 2000–2010 were also collected as a part of on-farm income. Off-farm income (i.e., wages for agricultural labor and Prosopis-related work) was estimated by multiplying the daily wage/monthly salary by the number of working days/months. In this paper, net income from crop production and wages for agricultural labor works were grouped as agricultural income, and the others (logging permit fee and wages for prosopis-related work (cutting and charcoal making) were grouped as prosopis-related income.

2.4 Price of Prosopis and its Supply Chain

Retail prices of raw Prosopis wood and the farm-gate prices of Prosopis charcoal were collected, respectively, from account books kept by the student hostel of Tamil Nadu Agricultural University (TNAU) and accounting notes recorded by Mr. Jaya Surian (Village P resident). No official statistical data are kept for prices of Prosopis. The TNAU student hostel had been buying raw wood from the same trader. Mr. Jaya Surian had been working as charcoal production manager since 2003; he sold his charcoal to a few companies. Although the Prosopis tree price might vary by location, we were able to estimate the price trend using these data.

To characterize the Prosopis supply chain, we interviewed several Prosopis traders, collectors, and users to ascertain the buying and selling prices of raw wood and charcoal. Focusing on relevant entities located near Village P, engineers and managers at the four biomass power plants (Figure 1) and the manager of two companies dealing in Prosopis charcoal were interviewed in June 2011 and August 2015, respectively.

3. Results and Discussion

3.1 Agricultural decline and expansion of Prosopis

The population and composition of the main workers in Village P in 1991, 2001, and 2011 are presented in Table 1. The village's total population shows a decreasing tendency. Sharp declines in population and household numbers were observed during 1991–2001. Considering the trend in main worker composition, it is apparent that many cultivators left the village during this period. The number of agricultural laborers decreased during 2001–2011, but the number of other workers increased. Table 2 presents the land holding conditions obtained from our 2011 survey. Landless households comprised 53.0% of all households. Marginal and small-scale landholders owning less than 2 ha made up 36.3% of all households. The total size of the area owned by sample farmers was 172.8 ha, which is only 31.7% of the village's registered agricultural area (545 ha). Although there is a gap between the number of households covered by government census and those of our survey, it is feasible that substantial amounts of agricultural land in this village were owned by non-residents.

Table 1 Population and the composition of main workers in village P

	Total population	Households	Cultivators		Agri. laborers		Other workers		Total main workers	
			Male	Female	Male	Female	Male	Female	Male	Female
1991	1,224	302	181	153	89	152	46	49	316	354
2001	1,150	273	70	20	146	171	99	29	315	220
2011	1,109	308	57	47	25	40	252	224	334	311

Data source: GOI (1991), GOI (2001), GOI (2011)

Table 2 Land holding condition in village P

Category	Land size	No of household	Area (ha)
Landless laborers		124 (53.0%)	
Landholder	< 1 ha	59 (25.2%)	36
	1 – 2 ha	26 (11.1%)	40.4
	2 – 4 ha	21 (9.0%)	62.4
	> 4 ha	4 (1.7%)	34
Total		234	172.8

Data source: Author's field survey (2011)

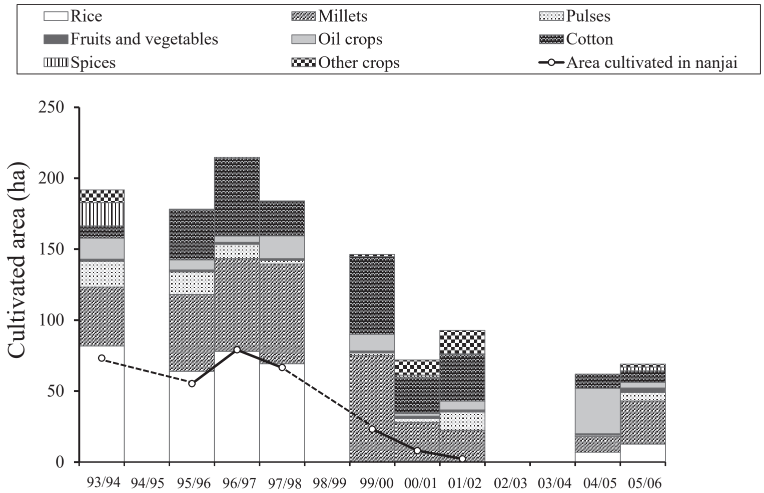
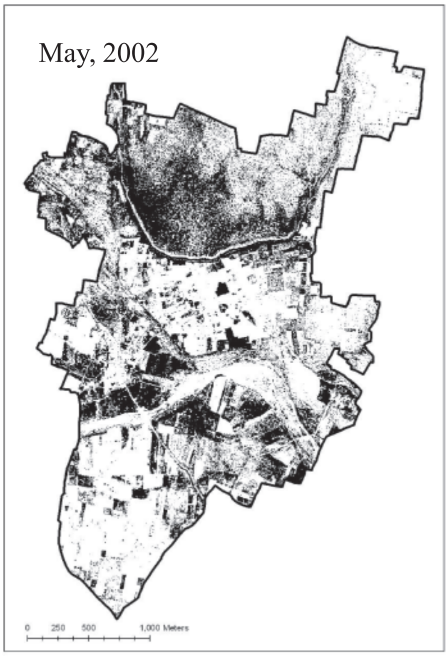


Figure 3 Inter-temporal changes in cultivated area from 1993/94 to 2005/06 agricultural seasons
Data source: Virudhunagar district statistical office

Figure 3 portrays the crop-wise cultivated area in the study village. From 1993/94 to 1997/98, the total cultivated area was between 175 ha (31.9% of registered agricultural area) and 215 ha (39.4%). Paddy cultivation was dominant in *nanjai*. The area under paddy cultivation was between 63.9 and 81.9 ha. Therefore, more than 60% of the registered *nanjai* area had been cultivated, despite the influence of unstable rainfall in this area. Millet (sorghum, pearl millet, and other minor cereals) cultivation was popular in *punjai*, but some farmers also cultivated pulses, cotton, oil crops (groundnut or gingelly), spices (chili and coriander), fruits and vegetables (tamarind, coconut, eggplant, and onion), and other crops, such as indigo or medical crops. However, most of the land in *punjai* was uncultivated: only 24–33% of *punjai* was cultivated between 1993/94 and 1997/98.

The village's cropping dramatically changed from the 1999/00 season. Paddy cultivation in *nanjai* decreased suddenly: it was only 2.2 ha in the 2001/02 season and



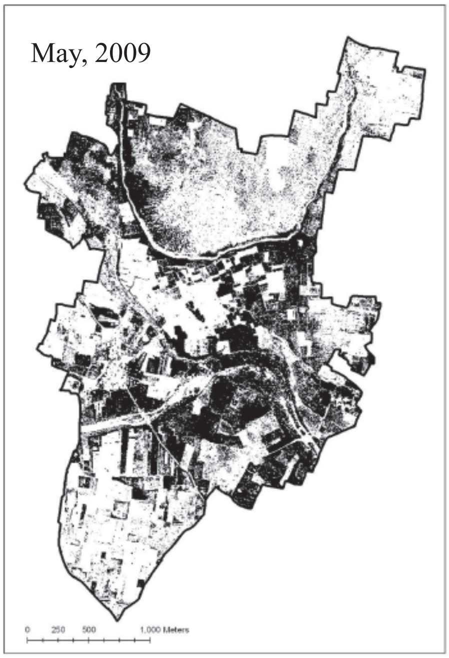


Figure 4 Prosopis tree coverage in village P
Data source: Sato (2013)

maintained a low cultivation ratio thereafter. The cultivated area in *punjai* also began to decrease in 2000/01: it was only 12.6% of total *punjai* area in 2005/06. The total cultivated area in 2005/06 was only 69 ha (12.7% of the registered agricultural area). Under such conditions, Prosopis trees began to invade both *nanjai* and *punjai*. Figure 4 presents the estimated Prosopis tree coverage in Village P in 2002 and 2009. The areas covered by Prosopis trees were 264 ha (34.9% of total village land) and 325 ha (42.4% of the total) in 2002 and 2009, respectively. Prosopis coverage, thus, increased by around 23% over these seven years. Furthermore, the coverage area shifted, as revealed by comparison with the village map (Figure 1). In 2002, Prosopis trees grew mainly inside the irrigation tank area and on agricultural land near the hamlet. However, in 2009, the area of Prosopis cover had moved to the eastern part of *nanjai*, where tank water access was worse than in the western part, and to the north-eastern part of *punjai*, close to the Gundar River.

Well irrigation in this village was not particularly common (Sato 2013). Therefore, it is generally expected that agricultural production in *nanjai* and that in *punjai* close to the river are higher than in other parts of the area. However, cultivation abandonment mainly occurred in such areas, despite the absence of drought, in terms of the rainfall amount, during this period (Solaimalai et al. 2014). River water flow and tank water storage are shown to have decreased dramatically from 1997/98, leaving farmers in such areas unable to properly cultivate crops due to the water deficit. Most irrigation tanks within this river basin are connected to the river. River water flows into the tank, and surplus tank water is channeled back to the river. Water used to irrigate paddy and other crops infiltrates into soil layers, recreating river water flow or being stored as tank water. However, the expansion of well irrigation in the upper river basin (Sato and Periyar Ramasamy 2011) might cause this water flow to change. Water flow within the river might begin to cycle only in the upper basin, i.e., water infiltrating into the upper basin's soil layer is used again in the same area through groundwater use. This would result in river water not reaching the lower basin. For lower basin farmers with no well water access, such tragedy is a common phenomenon in this area (Palanisami 2000; Kajisa 2012). Considering the decreasing tendency in household number between 1991 and 2001, landholders who cultivated the eastern part of *nanjai* and north-eastern part of *punjai* might have emigrated from this village. Prosopis then invaded such abandoned areas, transported in the dung of small ruminants: sheep and goat herders graze their animals not only on such abandoned land but also on common properties, such as the insides of irrigation tanks or tank bunds, which had been densely covered by Prosopis (Sato 2013). Therefore, one might infer that the expansion of well irrigation in the upper basin indirectly caused the rapid expansion of Prosopis in this village.

3.2 Rural Livelihood Depending on Prosopis

Despite the cultivation abandonment described above, a substantial number of villagers have remained in this village. It remains questionable how people in this village secured their livelihood under such conditions. Table 3 presents the effect of agricultural land use change on household income during 2000–2010. Having averaged 5,830 Rs in 2000, agricultural production in Village P had decreased by 85% in 2010. Income from agricultural wage labor also decreased by 47% during the period. The smaller decline in agricultural labor income, compared to that of agricultural production, perhaps indicates that laborers sought work in other villages. In contrast, the income from Prosopis logging permits – purchased by Prosopis cutting organizers or charcoal making managers from land owners with Prosopis-covered land – increased by 1,270% during 2000–2010; moreover, Prosopis-related labor work increased by 330% during this period. In total, income generated from Prosopis compensated the income decrease caused by agricultural

Table 3 Effect of agricultural land use changes on household income (Household average in constant prices Rupees; base year: 2000)

Income category		2000	2005		2010	
Agricultural income	Agricultural production	5,838	3,024	(52%)	850	(15%)
	Agricultural wage labor	1,456	1,376	(95%)	776	(53%)
	Sub total	7,294	4,400	(60%)	1,626	(22%)
Prosopis-related income	Logging permit fee	277	1,179	(426%)	3,519	(1270%)
	Prosopis related works	2,739	4,853	(201%)	9,047	(330%)
	Sub total	3,016	6,032	(200%)	12,566	(417%)
Total		10,310	10,432	(101%)	14,192	(138%)

Data source: Modified from Sato (2013)
Numbers in brackets indicate relative value to incomes in 2000.

abandonment. Therefore, the expansion of Prosopis in Village-P had a positive effect on household income (Table 3), influenced by the increment in Prosopis demand. Inter-temporal changes in the prices of Prosopis raw wood and charcoal are presented in Figure 5. Although some fluctuation of prices occurred, the retail price of Prosopis raw wood and farm-gate price of Prosopis charcoal more than tripled during 2002–2015. The Prosopis cutting area in this village also tripled during 2003–2009 (Sato 2013).

The British Colonial Government introduced Prosopis into India in 1877 (Perera et al. 2005). It has since spread to many parts of India since the 1960s (Saxena 1993), although the reason for the boom remains unclear. In the case of Village P, it might be related to the social forestry scheme started in the 1970s. The Tamil Nadu government introduced *Acacia nilotica* and other tree species with similar eco-physiological characteristics (i.e., tolerance to drought, submergence, and salinity) to those of Prosopis (Mahmood et al. 2001; Shiferaw et al. 2004). High coppicing ability is another important characteristic of Prosopis (Elfadl and Luukkanen 2003): Proposes tress recover to their original size after 2–4 years of clearance if the roots are left intact in the soil. Such eco-physiological characteristics matched the needs for fuel wood or charcoal in India's semi-arid zone (Perera et al. 2005; Saxena 1997). Prosopis charcoal has been used in tiny businesses, such as tea shops, restaurants, and brick-making.

However, such demand from small businesses was not the reason for the rural livelihood transformation shown in Table 3. For example, one tea shop annually consumed around 1.4 tons of Prosopis charcoal, which is equivalent to around 8.7 tons of raw wood. According to Patel (1987), the average annual yield of Prosopis raw wood is

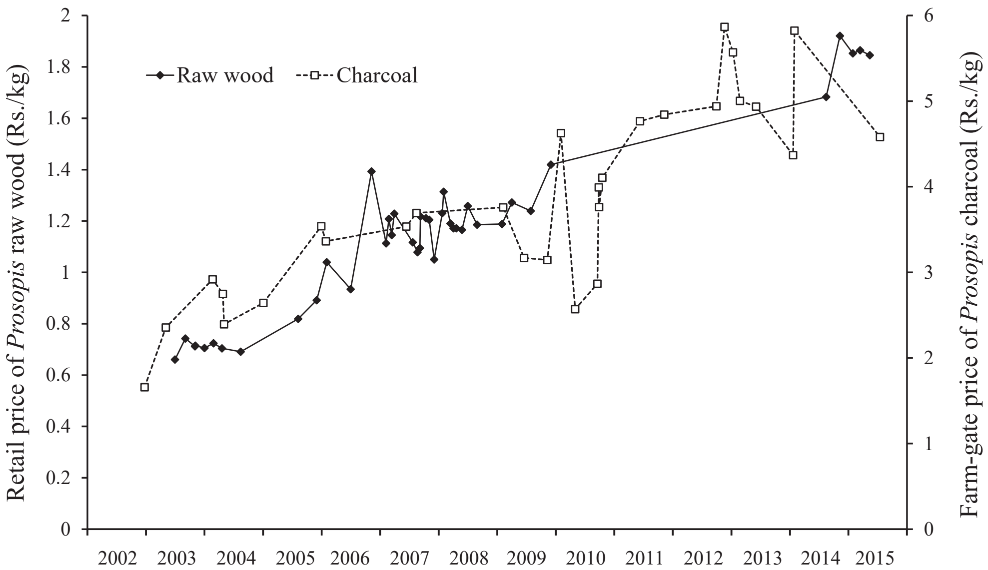


Figure 5 Inter-temporal changes in the prices of Prosopis (Constant prices; Base year: 2000)
Data source: Student hostel of TNAU, Mr. Jaya Surian

approximately 3 tons/ha. Therefore, even if 100 tea shops in the vicinity of Village P used Prosopis charcoal, the required Prosopis coverage would be 290 ha, which is less than the coverage in Village P in 2009. Prosopis tree cover expansion occurred not only in this village but also many nearby villages. Baka (2013) estimated the Prosopis coverage in Sattur Taluk, Virudhnagar district using Landsat images for 2009–2011. The results show that 36.2% of Sattur's geographic area was covered by Prosopis.

Figure 6 presents the Prosopis supply chain from Village P and nearby villages. Two factors triggered the Prosopis demand increase. One is the establishment of a biomass power plant near Village P (Figure 1(b)). Reflecting recent economic development, the energy demand not only in Tamil Nadu state but throughout India has also increased rapidly. Gross electricity generation in Tamil Nadu increased by 220% during 1997/98–2009/10, but generation from the state power sector (hydro, thermal, and gas) did not increase during this period. In 2009/10, the state power sector generated only 37.8% of total generation (GOTN 2006; 2012). To meet increasing demands for electricity, the central government established the Electricity Act in 2003, which removed entry barriers to private sector power generation. After 2003, as recognition of the need to tackle global warming increased, the central government also began to promote the construction of

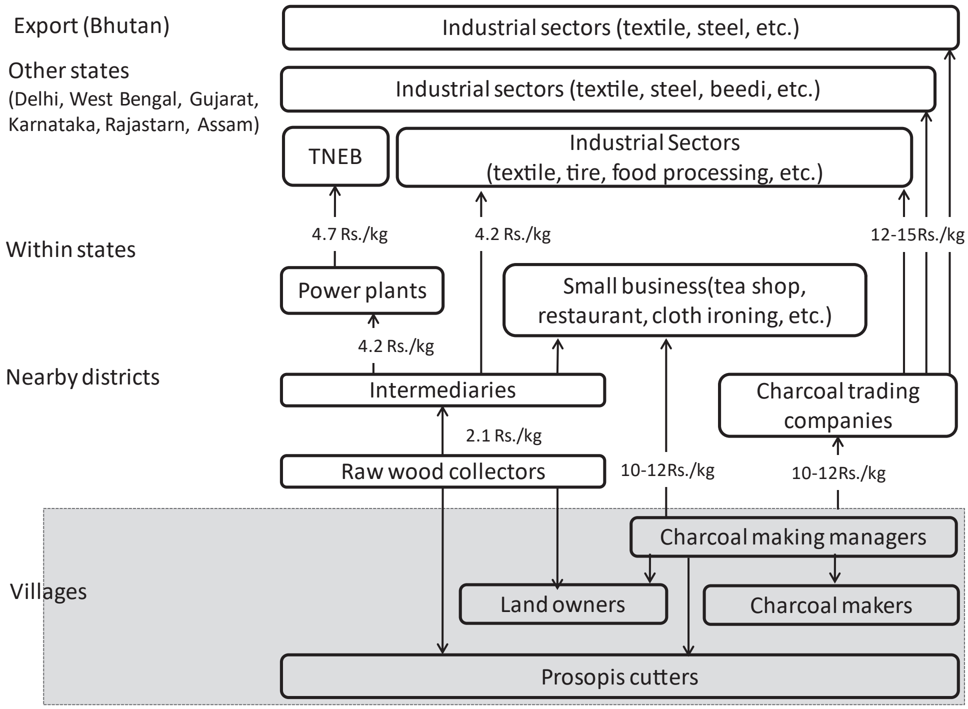


Figure 6 Prosopis supply chain
Numbers in the figure indicate the price of Prosopis (Rs.·kg^{-1})
Data source: Author's field surveys (2011 and 2015)

biomass power plants. Consequently, several private biomass power plants have been established in Tamil Nadu. The installed capacity of the biomass power plant increased by 1110% from 2004/05 to 2009/10 (GOTN 2006; 2012). Four biomass power plants were established near Village P during 2006–2009 (Sato 2013). The energy sources of these plants varied, but Prosopis was commonly used. The daily Prosopis raw wood requirement of each plant was 100–280 tonnes (36,000–102,000 tonnes annually), which is equivalent to an area of Prosopis covered land of 12,000–34,000 ha. Prosopis raw wood collectors based outside Village P hired village residents for their Prosopis cutting teams. The collected raw wood was sold to intermediaries, who sold it on to power plants (the biggest purchasers by volume), industrial sectors, and small businesses. It is noteworthy that the price of raw wood doubled through intermediaries, although they usually cover transportation costs.

The other factor increasing Prosopis demand was the manufacturing sector. When the author visited the study area in August 2015, two biomass power plants near Village P had already stopped using Prosopis. According to the interview with power plant officer, the main cause of this halt was the long-term disparity between the continual increase in the price of Prosopis raw wood and the static purchasing price paid by the state electricity board and industrial sectors. Today, almost all the Prosopis harvested in the village is used to make charcoal. Prosopis charcoal production is highly labor intensive. According to the survey data, Prosopis charcoal making for 1 ha of land requires 210 person-days of labor. If a Prosopis field is cleared every three years, this work creates 70 person-days of annual employment, which is more than the labor requirement for sorghum production (63 person-days/ha in this area). Village P's charcoal production managers sell to five charcoal trading companies located about 30 km east of the village. These companies' annual trading amounts of Prosopis charcoal are around 12,000 tonnes, which is equivalent to around 25,000 ha of Prosopis annual production. These companies sell charcoal to industrial sectors not only within Tamil Nadu but also in other states and in Bhutan. Steel industries use Prosopis charcoal to make sponge iron (Spate Irrigation Network Foundation 2011), textile companies use it for cloth ironing, and beedi companies might use it for drying tobacco leaves. Charcoal is exported by train with state governments providing subsidies as high as 25% of the transportation costs.

Although the main source of Prosopis demand shifted from the power sector to the industrial sector, demand increased continuously, as depicted in Figure 5. This explains how Village P's residents were able to secure their livelihood under conditions of agricultural decline. Such transformation in rural livelihoods was enabled by the combination of Prosopis trees' ecophysiological characteristics (tolerance to drought, submergence, and salinity; high coppicing ability), institutional support for Prosopis use (Electricity Act 2003; government subsidies on charcoal transportation), and technology (power plants to generate electricity from Prosopis; traditional charcoal making technologies). This case study underscores the possibility of reducing poverty in semi-arid rural areas without securing additional irrigation water.

However, the expansion of Prosopis also has a negative effect on agricultural production. Responding to NGO actions, Madurai High Court ordered the eradication of Prosopis from a water-spread area in 2014 because Prosopis trees consume much groundwater during their growth. Tromble (1977) shows that evapotranspiration from land in Arizona, where a Prosopis canopy covers more than 80% of the land, was similar to with potential evapotranspiration. Heavy pruning of Prosopis (which is usual in the study area) has been found to increase CO_2 assimilation corresponding to its groundwater use (Elfadl and Luukkanen 2003). El-Keblawy and Al-Rawai (2007) report that Prosopis inhibited the growth of neighboring plant communities, which might result from the allelopathic effect of Prosopis litter. The merits of its eco-physiological characteristics for residents in dryer areas can become problems for farmers in wetter areas. Considering such characteristics, clear boundary-setting between cropland and Prosopis land might be necessary for sustainable watershed management in this area.

4. Conclusion

This case study specifically assessed the process of livelihood transformation in a village with limited water access. Tank water storage decreased dramatically due to decreasing river water flow. Many farmers who owned agricultural land with tank and river water access migrated due to crop failure. A large amount of the land they abandoned was subsequently invaded by Prosopis through the rearing of sheep and goats. However, the establishment of biomass power plants, as part of a government initiative, and the development of industrial sectors increased the demand for Prosopis trees. Increased work opportunities related to Prosopis harvesting compensated for the decline in income from agricultural practices. Therefore, the expansion of Prosopis contributed to poverty reduction. The importance of Prosopis as a residential firewood and charcoal material has been suggested by several scholars (Baka 2013; Spate Irrigation Network Foundation 2011), but neither the Forestry Department nor the Agricultural Department of India has yet recognized this species as a resource. Appropriate government monitoring to support Prosopis use will have an additional positive effect on poverty reduction in this region.

Acknowledgements

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Notes

1) The following information was collected from villagers: (1) Number of household members, (2) Land holdings in *nanjai* and *punjai*, (3) Cultivated area per crop and their yields (including the extent of the area covered by Prosopis trees), (4) Logging permit fee from Prosopis collector, (5) Wages and number of days spent conducting agricultural labor, (6) Prosopis-related work (cutting or charcoal making), (7) Work provided through the National Rural Employment Guarantee Programme (NREGP), (8) Numbers and types of livestock, (9) Annual sales volumes and unit prices for livestock (buffalo, cow, sheep, goat, and chicken) and milk, (10) Non-farm work opportunities (type of work, working days, and salary), and (11) Other income, such as pension or remittances.

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