Abstract

Biofuels and Marginal Lands: An Interdisciplinary Examination of Jatropha Biodiesel Promotion in Tamil Nadu, India

Jennifer Elnora Baka
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How do biofuels grown on marginal lands impact energy security and rural livelihoods? This is an important question because recent biofuel policies have advocated growing biofuels on marginal lands to avoid conflicts with food security and land use change. In this dissertation, I examine this question in India because the country was one of the first to mandate the production of biofuels on "wastelands", an official government classification for marginal lands. My main focus is *Jatropha curcas* (hereafter Jatropha), a non-edible oilseed tree that can allegedly grow on marginal lands and whose seeds can be used to produce biodiesel. India initiated programs to grow Jatropha on 17.4 million hectares of wastelands throughout the country to support its biofuel policy objectives. Weaving together socioecological metabolism theory from industrial ecology and political ecology research on land use politics, I demonstrate how India's biofuel program is reshaping energy landscapes and agrarian livelihoods.

Based on fieldwork in the state of Tamil Nadu, I find that India's wastelands are not exactly marginal. In rural Tamil Nadu, many lands classified by the government as wastelands are currently covered with *Prosopis juliflora* (hereafter Prosopis), a tree widely used for household and industrial energy production. In Chapter 1 of my dissertation, I assess the relative energy services provided by Jatropha and Prosopis

through a comparative material and energy flow (MEFA) analysis in Sattur taluk, Tamil Nadu. Despite the government's promotion of Jatropha as an emerging energy source, I find that Prosopis provides approximately four to 15 times more useful energy to the regional economy than Jatropha biodiesel would. Further, the Prosopis economy has an energy return on investment (EROI) of 103 compared to a range of 1.1 to 10.4 for Jatropha depending on how, if at all, byproducts from biodiesel production are used. Lastly, I also find that the substitution of Jatropha for Prosopis is likely to engender significant livelihood changes due to the low availability of Prosopis substitutes for businesses and households and because of the limited employment opportunities for the landless and marginal poor in the Jatropha economy compared to the Prosopis economy.

In Chapter 2, I also find that the procedure of classifying wastelands is an inherently political process that narrowly defines these territories. These lands are simultaneously biophysical, economic, social and political spaces. Yet current assessment procedures prioritize the biophysical and economic dimensions. This occurs due to the discursive power of the term wasteland, which constructs these spaces as empty, underutilized territories used by equally wasteful persons. Since Colonial times, numerous wasteland development policies have been initiated to improve the productive capacity of wastelands and provide rural development benefits. Through my examination of these policies, I reveal how a similar policy recipe has been used to operationalize the programs. Yet, these policies fail to account for the differing perceptions of wastelands across stakeholders, which may in part explain the negligible rural development benefits resulting from the programs.

Through a micro-level study of a biofuel-related land acquisition in rural Tamil Nadu, India, in Chapter 3, I reveal how state subject relations are shaping modern land deal politics. Through its political construction of the concept of "wasteland" and its associated wasteland development program, the Indian state has facilitated a series of questionable land acquisitions, shaping agrarian livelihoods in the process. A class of land brokers has emerged to help carry out the state's project of converting "wastelands" to more "productive", state-defined uses such as biofuel cultivation or industrial expansion. Those whose lands have been acquired as part of these programs have increased their transition to wage labor, increasing the prolitarianization of agrarian communities. By documenting the mechanics of this "wasteland governmentality", this paper contributes to a political sociology of the state by unpacking the linkages between the state and agrarian subjects in the context of the "global land grab". Understanding these linkages will help enhance portrayals of the state within this literature and help develop more cogent strategies for reducing excessive land appropriations.

In summary, my research demonstrates the significance of land use politics in the context of energy policy. The Government of India's power to classify lands as wastelands obscures the energy and livelihood services these territories currently provide. Further, the ambiguous nature of current land classification procedures has in part facilitated questionable land acquisitions, which is fueling processes of agrarian change in rural Tamil Nadu. To better mitigate these outcomes, I recommend that policy makers more critically examine the concept of marginal lands and acknowledge the multiple dimensions defining these territories. Doing so will better reveal the tradeoffs that must be weighed in this current time period when the same lands are tasked with growing food and fuel and supporting rural livelihoods.

Biofuels and Marginal Lands: An Interdisciplinary Examination of Jatropha Biodiesel Promotion in Tamil Nadu, India

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Introduction

To minimize impacts to food security and environmental quality, biofuel advocates have begun recommending growing biofuels on marginal lands as it is widely held such lands are unsuitable for food production and are not large stores of carbon (Tilman, Hill et al. 2006; Campbell, Lobell et al. 2008; Fargione, Hill et al. 2008; Rathmann, Szklo et al. 2010). These advocates further claim that locating biofuels on such lands could offer development benefits to the rural poor through added employment and agricultural opportunities (Francis, Edinger et al. 2005; Brittain and Lutaladi 2010). However, many assumptions underlying these claims are under-researched.

First, it is unclear how lands are classified as marginal, who is responsible for the classifications and how this classification might vary across political scales and classes. Also embedded in this designation is the presumed inability of such lands to support agricultural production. However, this obscures the subsistence services such lands offer, such as for fuelwood and fodder gathering. Despite these uncertainties, interest in situating biofuels in marginal landscapes persists as evinced most clearly by India's National Biodiesel policy which mandates the use of non-edible feedstocks such as *Jatropha curcas* (hereafter Jatropha) grown exclusively on "wastelands", an official government classification for marginal lands (MNRE, 2009).

Focusing on the emergence of Jatropha biodiesel in Tamil Nadu, India, this dissertation critically examines the concept of wastelands using an interdisciplinary framework of industrial ecology and political ecology. This integrative framework offers perspectives on how biofuel production is reshaping agrarian livelihoods in a manner that has not been previously considered in the literature.

As land is now being tasked with growing food and fuel and supporting rural livelihoods, this dissertation reveals the significance of land use politics within energy and agricultural policy. I reveal how the Government of India's power to classify lands as wastelands obscures the energy and livelihood services these territories currently provide. Further, the ambiguous nature of current land classification procedures has in part facilitated questionable land acquisitions, which is fueling processes of agrarian change in rural Tamil Nadu. The findings of this research are broadly applicable to all countries promoting biofuel production.

Theoretical Framework

Theoretically, this dissertation weaves together socioecological metabolism theory from industrial ecology and land use politics research from political ecology. This framing provides new insights into how biofuels are reshaping agrarian livelihoods and the political processes governing these changes in a manner previously not considered in the literature.

Both industrial ecology and political ecology explore the impacts of human environment interactions (Robbins 2004; Graedel and Allenby 2010). Both fields are united in the belief that human environment relationships co-evolve and are mutually reinforcing. Yet both fields emphasize different variables. Industrial ecology examines the flow of energy and materials through society while political ecology explores the relations of power governing these resource flows.

In this dissertation, I draw upon socioecological metabolism theory from industrial ecology as a basis for evaluating Jatropha cultivation on wastelands. This theory examines the interconnectedness of human environment interactions by assessing the flow of energy and materials through society. Of particular interest is how these relationships change at "transition" moments in human society (ie. transitions from agrarian to industrial society), referred to as "socioecological regimes" (Fischer-Kowalski and Haberl 2007). Evaluating patterns of land use change is at the center of socioecological metabolism research as it is widely held that human engagement with landscapes drive socioecological transitions (Fischer-Kowalski and Weisz 1999). While some theorists have asserted socioecological metabolism can serve as a basis for interdisciplinary engagement with qualitative social sciences (Haberl and Geissler 2000), little research has been done in this regard. To date, most socioecological metabolism studies have focused on evaluating the historic flow of energy and materials through society and corresponding patterns of land use change, primarily at the national level (Fischer-Kowalski and Haberl 2007).

As I demonstrate in this dissertation, coupling political ecology scholarship with socioecological metabolism can help to more critically examine the qualitative dimensions of socioecological regimes. As defined by Watts, political ecology seeks "to understand the complex relations between nature and society through a careful analysis of what one might call the forms of access and control over resources and their implications for environmental health and sustainable livelihoods" (Watts 2000: 257). Of particular interest is how these relations impact historically disenfranchised communities, such as the marginal and landless poor (Robbins 2004). Typically, political ecology is normative in its approach believing there are "likely better, less coercive, less exploitative and more sustainable ways of doing things" (Robbins 2004: 12). Further, and unlike socioecological metabolism, political ecologists frequently critique policy making, in terms of policy design, implementation and outcomes.

I draw upon Mosse's (2004) political ecology research on policy making combined with Focault's theory of discursive power to evaluate the politics of wasteland development in India. I reveal how wastelands are politically constructed spaces and how the process of wasteland assessment obscures the livelihood services these territories provide to agrarian communities. Drawing upon socioecological metabolism research methods, I demonstrate how existing biomass stocks on India's wastelands currently provide more energy services than would a Jatropha economy. Lastly, engaging with political ecology research on the unintended outcomes of policy (Ferguson 1994; Scott 1998; Li 2007), I document how the ambiguity of wasteland assessments combined with India's support of Jatropha cultivation on wastelands has facilitated questionable land acquisitions in rural South India. Theoretically, this dissertation contributes to emerging political ecology scholarship on land investments and industrial ecology literature on socioecological research and builds a bridge for future engagements between these fields.

Jatropha Policy History

Interest in using Jatropha as a biofuel largely began around 2003 when the Government of India announced an ambitious plan to displace 20% of diesel fuel use with Jatropha biodiesel by 2012 (GOI 2003). The government identified Jatropha as its primary biodiesel feedstock and called for establishing a National Mission on Biofuels to cultivate Jatropha on over 13 million hectares (ha) of wastelands throughout the country (GOI 2003). Further, the government hoped the plan would be a major 'pro-poor initiative' by providing new employment and income opportunities to small farmers and landless, marginalized communities. Although this plan was never put into law, numerous companies and state governments established Jatropha programs and by 2008, over 450,000 ha were estimated to be under cultivation (GEXSI 2008).[1] According to GEXSI's estimates, India was the world's leading Jatropha cultivator and was predicted to remain one of the leading cultivators through 2015.

In December 2009, the Government of India enacted a National Policy on Biofuels (MNRE, 2009). The Ministry of New and Renewable Energy will implement the policy

[1] At present, the GEXSI survey is the most comprehensive database of Jatropha activity. Based on the fieldwork conducted for this dissertation, no governments are systematically compiling and distributing this information. The GEXSI gathered its data through an online survey of Jatropha companies (160 responses were received) and by interviewing 176 Jatropha experts in 55 countries (GEXSI, 2008). They did not conduct site visits to verify their survey or interview findings, which raises concerns about the validity of the results.

while a newly formed body headed by the Prime Minister, the National Biofuel Coordination Committee (NBCC), will oversee the policy (MNRE, 2009). The policy established a blending target of 20% by 2017 for both biodiesel and ethanol, subject to periodic revision (MNRE, 2009).

While the current policy does not specifically recommend the use of Jatropha biodiesel, the feedstock conditions laid out by the policy strongly imply a resurgence in Jatropha activity throughout the country. The policy states only 'non-edible oilseeds grown on wasteland, degraded or fallow land in forest and non-forest areas' should be used for biodiesel production (MNRE, 2009: 7). These conditions, the government stipulates, set India's biofuel program apart from other international efforts because they help to ensure biofuel production does not interfere with food production. Jatropha achieved prominence in the global biofuels debate because of its alleged ability to grow in degraded areas away from food cultivation. Further, it is the most commercially developed feedstock and will undoubtedly play a key role in India's biodiesel industry for years to come.

Chapter Outline

In Chapter 1, I evaluate the relative energy services India's wastelands currently provide to communities. Using case studies of Jatropha activity in southern Tamil Nadu, I discovered *Prosopis juliflora* (hereafter Prosopis) biomass from wastelands currently supports a significant rural and industrial energy economy. Through a comparative material and energy flow analysis (MEFA), I find the existing Prosopis economy provides 3.6 to 15.2 times more useful energy than a Jatropha economy and has an energy return on investment (EROI) of 103 compared to 1.1-10.4 for Jatropha. As few biomass substitutes exist for Prosopis, household users indicated they would substitute towards Liquefied Petroleum Gas (LPG) or kerosene in the absence of Prosopis while businesses indicated they would move elsewhere or shutter their shops. These outcomes complicate the potential energy and environmental security benefits of biofuels.

In Chapter 2, I evaluate the politics of wasteland classification procedures within India and demonstrate how the discursive power works to narrowly define the territories. These lands are simultaneously biophysical, economic, social and political spaces. Yet current assessment procedures prioritize the biophysical and economic dimensions. This occurs due to the discursive power of the term wasteland, which constructs these spaces as empty, underutilized territories used by equally wasteful persons. Since Colonial times, numerous wasteland development policies have been initiated to improve the productive capacity of wastelands and provide rural development benefits. Through my examination of these policies, I reveal how a similar policy recipe has been used to operationalize the programs. Yet, these policies fail to account for the differing perceptions of wastelands across stakeholders, which may in part explain the negligible rural development benefits resulting from the programs.

Through a micro-level study of a biofuel-related land acquisition in rural Tamil Nadu, India, in Chapter 3, I reveal how state subject relations are shaping modern land deal politics. Through its political construction of the concept of "wasteland" and its associated wasteland development program, the Indian state has facilitated a series of questionable land acquisitions, shaping agrarian livelihoods in the process. A class of land brokers has emerged to help carry out the state's project of converting "wastelands" to more "productive", state-defined uses such as biofuel cultivation or industrial expansion. Those whose lands have been acquired as part of these programs have increased their transition to wage labor, increasing the prolitarianization of agrarian communities. By documenting the mechanics of this "wasteland governmentality", this paper contributes to a political sociology of the state by unpacking the linkages between the state and agrarian subjects in the context of the "global land grab". Understanding these linkages will help enhance portrayals of the state within this literature and help develop more cogent strategies for reducing excessive land appropriations.

Lastly, I present future research directions in my concluding chapter. I offer initial thoughts on how my findings can be translated back into policy. Further, because of increased global interest in using land to service both energy and food demands, I explore how an integrated industrial ecology and political ecology framework can be useful for evaluating global land investments.

Chapter 1. Wastelands and Biofuels: A Comparative MEFA Analysis of Tamil Nadu's Biomass and Biofuel Economies

Jennifer Baka, Rob Bailis, Grishma Jain, Megha Shenoy

Abstract

India's current biofuel policy mandates the use of non-edible oilseeds such as Jatropha curcas grown only on wastelands, a government classification of marginal lands. However, contrary to being barren landscapes as the term wasteland might connote, the wastelands of southern Tamil Nadu are endowed with Prosopis juliflora, which is used as an energy feedstock for a host of rural and industrial users. Through a comparative material and energy flow accounting (MEFA) framework, we find the existing Prosopis economy provides 3.6 to 15.2 times more useful energy than a hypothetical Jatropha economy and would result in an energy return on investment (EROI) of 103 compared to 1.1-10.4 for Jatropha. Further, the Prosopis economy is far less materially intensive as only diesel is required for transportation and ignition purposes. Overall, replacing Prosopis with Jatropha would likely complicate, rather than improve energy security as all biodiesel produced would be exported from the region. Further, current Prosopis users indicated that no suitable substitutes are available for Prosopis, that they would substitute towards other tree species or agricultural wastes or take up kerosene or LPG. As an extreme outcome, some charcoal and brick manufacturers indicated they would shutter their businesses if faced with a Prosopis shortage. As the availability and energy quality

of agricultural wastes and other tree species is uncertain and as India is currently a net importer of kerosene and LPG, India's assertions that a wasteland centered biofuel program can improve energy security and rural welfare warrant future evaluation.

Introduction

An oft-cited proposal in support of sustainable biofuels calls for cultivating feedstocks on marginal lands as it is widely held such lands are unsuitable for food production and are not large stores of carbon. Government agencies (Cramer, Wissema et al. 2006; Gallagher 2008), certification organizations (Roundtable on Sustainable Biofuels 2009) and academic researchers (Hill, Nelson et al. 2006; Tilman, Hill et al. 2006; Fargione, Hill et al. 2008; Tilman, Socolow et al. 2009) have made this recommendation. It is also believed such schemes would offer development benefits to rural communities, particularly to marginal farmers and the landless poor in developing countries (Brittain and Lutaladi 2010). Coupling both these themes, the Government of India recently established a 20% biodiesel blending target by 2017 using only non-edible oilseeds grown on wastelands, the government term for marginal lands (Government of India 2009).

Although India's policy does not identify preferred feedstocks, it is likely *Jatropha curcas* (hereafter called Jatropha) will be the principal feedstock as it is the most commercially advanced non-edible oilseed. As result of past efforts at Jatropha promotion (Government of India 2003), India is currently one of the world's leading cultivators, according to a global market study (GEXSI 2008).

Further, the policy gives no guidance on how wasteland areas will be identified and mobilized for biofuel production. Based on interviews with key stakeholders and observations of established Jatropha plantations, marginal lands currently covered with the invasive tree species, *Prosopis juliflora* (hereafter called Prosopis) are the areas of primary interest. However, Prosopis biomass resources currently support a host of decentralized and centralized energy applications from household fuelwood to electricity generation. Based on current practices, Jatropha companies are removing Prosopis to establish plantations. Thus, India's biofuel and biomass programs are competing for the same lands, which may have perverse impacts on energy security and economic development, particularly in rural communities (OECD/IEA 2010).

Through a case study of Jatropha promotion in rural Tamil Nadu, India, this paper examines these tradeoffs through a sociometabolic framework (Fischer-Kowalski and Haberl 2007). This framework, rooted in material and energy flow accounting (MEFA), examines how changes in human environmental relationships, such as those brought on by replacing Prosopis with Jatropha, impacts the structure of socio-ecological systems as a whole. It enables a simultaneous consideration of environmental, economic and social impacts by critically examining how patterns of resource mobilization are changing in light of policy shifts (Haberl 2002). As such, it can offer a deeper and more contextualized analysis of biofuel policies going beyond the insights offered by life cycle analysis (LCA), one of the most commonly used methods to evaluate biofuel production.

In this paper, we present a comparative MEFA of the Prosopis and Jatropha economies in Sattur taluk[2], Tamil Nadu. We examine how India's Jatropha program is altering energy and material flows in rural Tamil Nadu and what implications these potential changes

[2] A taluk is an administrative division in India.

have on the efficacy of the biofuel program. Further, we examine what implications these potential changes in energy and material flows have on energy security, one of the main concerns motivating biofuel policies in India (Government of India 2003).

The next section reviews the literature on the use of LCA to evaluate biofuels and on socioeconomic metabolism. The fieldsite and methods are described in Section Three, followed by a review of analysis methods in Section Four. Results are presented in Section Five and their implications are presented in Section Six.

Literature Review

Evaluating the land use change impacts of biofuel production is one of the main research focuses and areas of greatest uncertainty in current biofuel research. To estimate the direct land use change (dLUC) impacts[3] of biofuel production, Fargione, et al (2008) introduced the concept of "carbon debt", which estimates the time required to "pay back" for the initial release of carbon from land conversion by substituting fossil fuels with biofuels. Recognizing the linkages between land fertility and carbon sequestration potential, Fargione, et al (2008) advocated cultivating biofuels on marginal and abandoned cropland to minimize carbon deficits. However, the exclusive focus on carbon sequestration potential obscures other services that marginal lands may provide. As this study demonstrates, the biomass feedstocks on marginal lands in India support a sizeable energy economy of both rural and urban consumers.

[3] Direct land use change refers to the impacts resulting from initial conversion of lands to biofuels.

Indirect land use change (iLUC), the broader agricultural cultivation decisions that result from expanded biofuel production, has been a second main avenue of inquiry. Using partial and general equilibrium models from economics, researchers have attempted to estimate how agricultural markets would respond in light of increased biofuel production and what land requirements would result. Beginning with the seminal work of Searchinger, et al, (2008), researchers posit the iLUC impacts of biofuels would exceed the annual environmental savings from displacing fossil fuels with biofuels. This approach has been critiqued for its high degree of uncertainly, particularly regarding the economic modeling and agriculture productivity assumptions (Wang and Haq 2008; Whitaker and Heath 2008; Plevin, O'Hare et al. 2010; McKone, Nazaroff et al. 2011). As such, the land use impacts of biofuel production have been identified as one of seven "grand challenges" in biofuels research (McKone, Nazaroff et al. 2011).

At the core of both dLUC and iLUC studies is life cycle analysis (LCA), which is commonly used to evaluate the greenhouse gas impacts of biofuel production and use. Yet as a recent meta-study of 67 biofuel LCAs by van der Voet, et al (2010) demonstrates, LCA studies are also characterized by a great deal of uncertainty because of modeling assumptions and data uncertainties, which makes it difficult to draw generalized conclusions. Thus, research into the land use impacts of biofuel production is an emerging area of research presently characterized by high levels of uncertainty. Further, current LCA-based models are focused on evaluating the greenhouse gas (GHG) impacts of biofuel production, which does not fully capture the potential changes in human environment relations brought on by biofuel production.

To date, a number of LCAs have been performed for Jatropha biodiesel in a variety of geographic settings and cultivation techniques. In their broad survey of Jatropha cultivation practices around the globe, Almeida, et al (2011) find that excluding land use change impacts, Jatropha biodiesel production utilizes eight times less nonrenewable energy than conventional diesel fuel and reduces GHG emissions by 51% on a lifecycle basis. Other studies considering the use of straight Jatropha oil for decentralized electricity generation (Gmuender, Zah et al. 2009) and Jatropha oil for aviation biofuel reveal equally favorable environmental performance (Bailis and Baka 2010). Cultivation, transportation and transesterification have been the most influential production stages across the studies.

Various Jatropha LCAs (Reinhardt, Gaertner et al. 2007; Bailis and Baka 2010) have included direct land use change (dLUC) estimates, typically using default values from the IPCC's "Guidelines for National Greenhouse Gas Inventories"(IPCC 2006; Fargione, Hill et al. 2008). These studies demonstrate that the impacts of direct land use change are least-impactful when feedstock cultivation is restricted to marginal or degraded lands, such as lands with little to no vegetation (Reinhardt, Gaertner et al. 2007) or former agro-pastoral lands (Bailis and Baka 2010).

However, as Bailis and McCarthy (2011) demonstrate, the IPCC land classifications, which include six land categories[4], may be too broad to adequately capture the land use change dynamics of biofuels. In their study of Jatropha plantations in Central Brazil and Tamil Nadu, India, the authors find that replacing existing biomass stock with Jatropha on unmanaged *caatinga* woodlands in Brazil would result in a 10-20 year carbon debt while replacing Prosopis lands with Jatropha in Southern India would result in negligible changes to carbon stocks. Yet both the *caatinga* and Prosopis lands are considered marginal lands in government classifications and would likely be clumped into the "other lands" category of IPCC accounting. These findings add another layer of uncertainty to the biofuels and marginal lands debate as the carbon impacts are likely to be site specific.

Lastly, a carbon assessment of biofuels and marginal land policies will not capture the local dynamics of a biofuel transition. Because of the varying tenure regimes on marginal lands (Ostrom 1990), introducing biofuel production into these spaces could impact rural livelihoods. Because existing biomass feedstocks on the marginal lands of Tamil Nadu currently serve as feedstocks for rural and industrial energy users, we selected an alternative industrial ecology framework to assess the potential land use change impacts of replacing Prosopis biomass with Jatropha biofuel, socioecological metabolism.

Socioecological metabolism evolved from socioeconomic metabolism, which evaluates how societies are sustained through engagement with the biophysical world (Ayres and Simonis 1994; Fischer-Kowalski 1997; Fischer-Kowalski and Haberl 1997; Matthews,

[4] The categories are forest land, cropland, grassland, wetlands, settlements and other lands.

Amann et al. 2000). The concept envisions society as a physical input-output system drawing material and energy from its environment for its maintenance and reproduction. The core of socioeconomic metabolism is material flow analysis (Matthews, Amann et al. 2000; Eurostat 2001) and energy flow analysis (Haberl 2001), which characterize the metabolic profile of the system under examination. Methods of material and energy flow accounting are compatible with social and economic modeling statistics, enabling the integration of ecological and economic data and modeling (Fischer-Kowalski and Haberl 2007; Singh, Haberl et al. 2010).

Socioecological metabolism was established to more fully capture the land use impacts of society-nature interactions, which are not directly assessed in material and energy accounting. Land use is conceptualized as "colonization of nature" (Fischer-Kowalski and Weisz 1999), which recognizes human interventions into ecosystems are intentionally undertaken in order to modify natural systems to best meet society's needs. A principle metric to assess colonization is a more streamlined version of human appropriation of net primary production (HANPP) (Vitousek, Ehrlich et al. 1986), which is the difference between net primary production (NPP) of potential biomass stocks and the balance remaining after human intervention (Haberl, Erb et al. 2007).

For this study, an alternative land use change metric is used, energy return on investment (EROI), as it better facilitates a comparison of the energy efficiency of biomass and biofuel production systems (Haberl, Fischer-Kowalski et al. 2004). EROI is a ratio of the useful energy provided by a system to energy inputs required to support the system

(Hammerschlag 2006; Cleveland 2008). For the purposes of this study, HANPP might obscure a comparison of biomass and biofuels as much of the biofuel system remains as stock (ie. trees are left in tact through cultivation), resulting in a lower (ie. more favorable) HANPP of biofuels versus biomass. However, this stock is not used as an energy source, a facet not captured by HANPP. Other socioecological metabolism studies have similarly used EROI as an indicator of land use change (Singh, Gruenbuehel et al. 2001).

Collectively, energy and material flow accounting plus a colonization evaluation comprise material and energy flow accounting (MEFA) (Fischer-Kowalski and Haberl 2007). MEFA is commonly used to evaluate societal "transitions" between different sociometabolic regimes (ie. subsistence states), such as hunter gather, agrarian and industrial modes of production. Changes in energy systems are often the driving factor enabling regime transitions (Sieferle 2001; Sieferle 2003). As Krausmann's (forthcoming) evaluation of Vienna's energy metabolism from 1860 to 2006 demonstrates, energy transitions often facilitate changes to transportation infrastructures and agricultural productivity, which impact urbanization and population growth rates.

To date, most MEFA have been applied across geographic scales from country-level (Haberl 2002; Krausmann, Haberl et al. 2004), village-level (Gruenbuehel, Haberl et al. 2003) and in island settings (Singh, Gruenbuehel et al. 2001). To our knowledge, MEFA has not previously been applied for policy evaluation. However, as India's proposed biofuel transition marks a significant change in the country's energy provision system, the MEFA framework is applicable to analyze this transition. While only a small geographic region of India was evaluated for this study, the analysis provides insights into the country's current socioecological profile and how the country's energy system may transition if the country continues its support of biofuels. The findings are thus salient in a variety of policy dialogues, particularly energy, agriculture and agrarian change.

Lastly, MEFA is a foundation for integrating social and ecological research, given the diverse social science origins of socioecological metabolism. Using a systems theory approach, classic works in ecological anthropology examined how changing patterns of energy procurement altered cultures and modes of subsistence (White 1953; Rappaport 1971). Further, Boserup, whose work has been highly influential in sustainability sciences (Turner and Fischer-Kowalski 2010), explored how agrarian communities modified production techniques in response to environmental stressors and demographic shifts (Boserup 1965). Many of these works draw on classic ecological research on systems evolution, particularly Holling's (1973) adaptive cycle. Going forward, MEFA will contribute to the emerging field of long-term socioecological research (LTSER). While still in a conceptual phase, LTSER research aims to rigorously assess how society-nature interactions evolve across a variety of spatial, temporal and geographic scales (Singh forthcoming).

Field Site and Methods

Fieldwork took place between December 2010 and February 2011 in Sattur taluk, Virudhunagar District, Tamil Nadu (Figure 1). Tamil Nadu is the southeastern most state in India and Virudhunagar District is located in the south central portion of the state. Sattur taluk is located in the southern portion of the district on the central plains. While dry land agriculture is currently the main occupation, primarily corn, cotton and pulse farming, Sattur is in the midst of an industrial transition with an increasing number of fireworks and match factories moving into the area (Virudhunagar District Collector 2009). Average rainfall for the district is approximately 830 millimetres per year and black soil is the predominant soil class (Virudhunagar District Collector 2009).

Sattur was selected because of its diverse mix of Prosopis uses and its history of Jatropha promotion. According to the 2010 *Wastelands Atlas of India*, approximately 1.4% (5,838 hectares (ha)) of Virudhunagar's geographic area (428,300 ha) is covered with scrub brush, the wasteland category often dominated by Prosopis coverage (Government of India 2010).[5] Statewide, approximately 3.2% of the total geographic area of Tamil Nadu is classified as scrub brush wasteland while just over 7% of the state is classified as wasteland (Government of India 2010).[6] In addition to its use as a household fuelwood, Prosopis is used as a fuel by a host of industries in the region, including a 10-megawatt

[5] Based on interview (11/18/10) with Dr. M. Ramalingam, Chair of Anna University's Institute of Remote Sensing, the department tasked with compiling the *Atlas* for Tamil Nadu.
[6] The *Wastelands Atlas* classifies wastelands into 23 separate categories.

(MW) power plant.[7] Further, although the Jatropha market is at a standstill in the region, companies tried to establish Jatropha plantations on wastelands in Sattur during 2004-05 (Baka 2011) and at least two Jatropha companies are still operating in the neighboring taluk of Aruppukkottai (Figure 1.1).[8]

Data for the MEFA analysis was gathered by surveying users of Prosopis and Jatropha. The current area of Prosopis in Sattur was estimated through remote sensing techniques.[9] Finally, we conducted a calorific analysis of Prosopis charcoal, Prosopis roots, Prosopis stems, Jatropha oil, Jatropha seedcake and an NPK analysis of Jatropha seedcake.[10] Each of these steps is described in more detail below.

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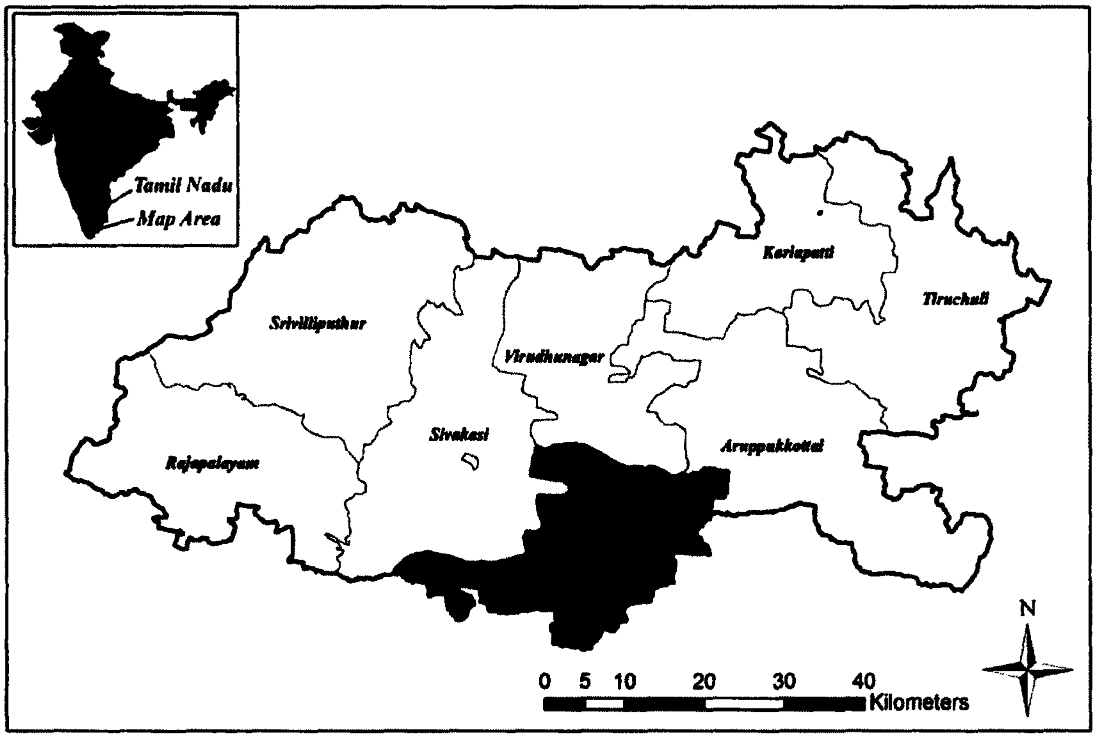
[7] As will be detailed further below, the power plant uses Prosopis for 90% of its feedstocks.

[8] Interview with D. Aristotle, General Manager, Emami Biotech (6/21/10) and interview with SA Alagarswamy, Director, ACS Alternative Fuels Private Ltd (10/27/10).

[9] Researchers at the Centre for Ecological Sciences, IISc Bangalore assisted with this component.

[10] We contracted with two private labs in Bangalore for these tests, SGS Labs and TUV Rheinland.

Figure 1.1: Sattur Taluk



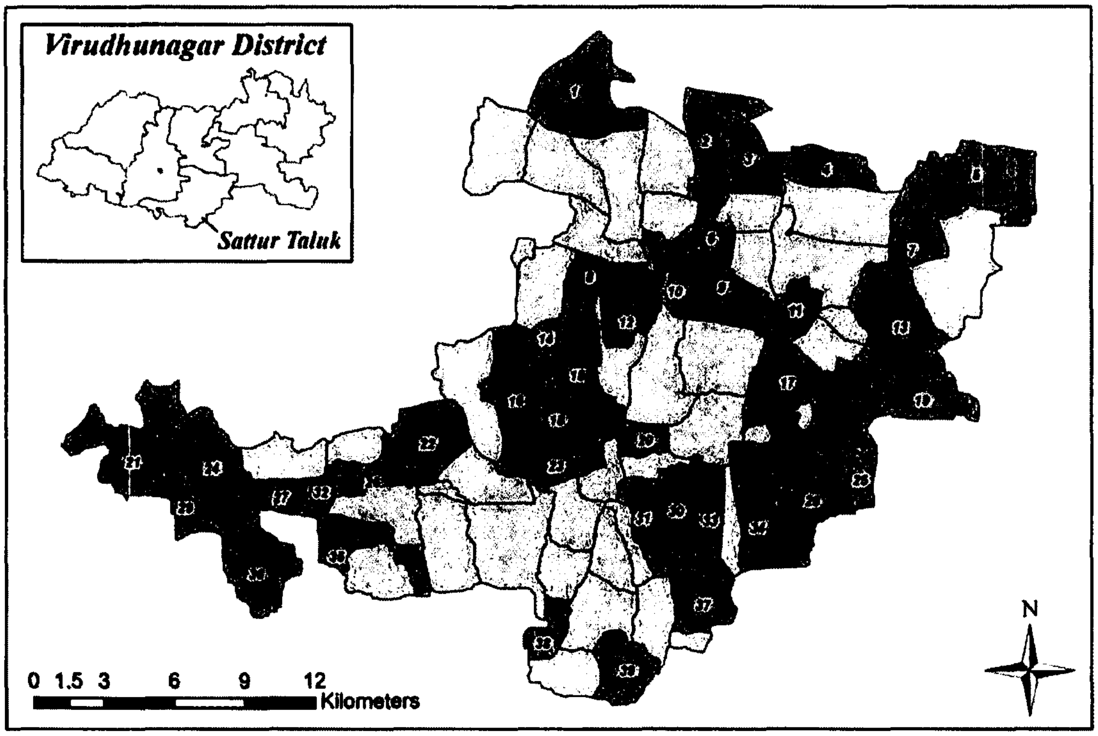
Prosopis Data Gathering

Sattur consists of 65 revenue villages.[11] We randomly sampled 39 villages (Figure 1.2) for our study to achieve a 95% confidence interval (Israel 1992). However, in the course of fieldwork, one village had been dissolved resulting in a sample of 38 villages. Through preliminary scoping trips to the region between June and November 2010, we identified the probable industrial users of Prosopis. Using industry data from the Virudhunagar

[11] Villages are classed in two ways: revenue and panchayat. Revenue villages are for the purposes of tax collection while panchayat villages are for the purposes of program administration. The borders do not always overlap. Sattur consists of 65 revenue villages and 46 panchayat villages.

government (Virudhunagar District Collector 2010)[12], we randomly selected industries within the study villages to survey.

Figure 1.2: Field Site Villages



[12] Data was accessed 12/1/10. However, it is no longer available online at the Virudhunagar District Collector's website.

Table 1.1: Survey Villages

Map No.	Village Name	Map No.	Village Name	Map No.	Village Name	Map No.	Village Name
1	Kumaralinga-puram	11	Melmadai/ Irrukungudi	21	Sevalpatti	31	Muliseval
2	Sandaivur	12	Chattrapatti	22	Kangarakottai/ Keelachalaiah puram	32	Servaikkara npatti
3	Golvarpatti	13	N. Mettupatti	23	Chinna Tambiyapuram	33	Ovvanayakk anpatti
4	Nallamanaya-kkanpatti	14	Muthulinga-puram	24	Tulukkankuri-chchi	34	Uppathur
5	Pappakudi	15	O. Mettupatti	25	Sinduvampatti	35	Uthupatti
6	Ammapatti	16	Surankudi	26	Sanankulam/ Sivasankapatti	36	Sippipparai
7	Attipatti	17	Nenmeni	27	Sankarapandiy apuram	37	Nallamuttan patti
8	Padantal	18	Ottaiyal	28	Ayyampatti	38	Peranyyanp atti
9	Allampatti	19	Mudittalain agalapuram	29	Kukanaparai	39	Kanjampatti
10	Kattalampatti	20	Chinnodai-ppatti	30	Subramania-puram	dark block	Sattur town

Additionally, the number of households in each village was obtained from the 2001 Indian census (Government of India 2001). Surveys were conducted with 115 households of the 22,582 households in the survey villages to obtain a 95% confidence interval. Households were randomly selected in proportion to village household population (Appendix 1.1).

Upon entering a village, we first conducted a survey with a village leader, in preference order of the panchayat president, vice president or clerk, in order to gather background information on the history of Jatropha and Prosopis in the village. This survey also gathered data on the main industrial users of Prosopis in the village to triangulate the government industry list. Through these surveys, we identified the main users of Prosopis in terms of volume to be the electric power plant, paper mills, brick makers, charcoal makers, rural homes, eateries, match factories and oil mills. Further, we surveyed 11 wood traders and wood cutters as there is an active Prosopis import and export trade in Sattur taluk. Table 1.2 summarizes the surveys conducted by user group and Appendix 1.1 details surveys by user group and location.

Table 1.2: Summary of Prosopis Surveys

User Group	# Surveys
Fuelwood Users	114
Power Plant	1
Charcoal Makers	4
Brick Makers	5
Match Factories	7
Eateries	11
Paper Mills	3
Oil Mills	2
Wood Traders	11
TOTAL	**158**

Jatropha Data Collection

As the Jatropha market in Sattur and throughout India as a whole is currently stalled (Kant and Wu 2011), we modeled the likely composition of a Jatropha economy through surveys of Jatropha establishments nearby Sattur. We used this data to construct a hypothetical Jatropha market in Sattur. As per guidelines in India's current biodiesel purchasing policy (Government of India 2005), we assumed all Jatropha biodiesel processed in Sattur would be shipped to the nearest government-run oil marketing corporation (OMC) in Karur, Tamil Nadu, 213 km northwest of Sattur.

One interview was with Emami Biotech, a company that had previously established a 300-acre Jatropha plantation in Ramnad, a district neighboring Virudhunagar to the east. Although Emami is no longer actively maintaining their plantation in Ramnad, the company has been an active player promoting Jatropha internationally, particularly within Ethiopia (Goswami 2009). We surveyed Mr. D. Aristotle, the General Manager of Emami Biotech, who was also responsible for Emami's activities in Ethiopia.[13] Additionally, we surveyed the plant manager at a Jatropha biodiesel facility in Aruppukkottai (Fig 1), ACS Alternative Fuels Private Ltd, to gather data on the energy and material requirements of Jatropha oil extraction.

Data was triangulated through a literature review of Jatropha LCAs, primarily (Reinhardt, Gaertner et al. 2007; Achten, Verchot et al. 2008; Whitaker and Heath 2008; Almeida, Achten et al. 2011). As no biodiesel transesterification unit currently exists in Virudhunagar, we relied upon literature values for these variables.

Model Assumptions and Design

We assembled the MEFA accounting framework in accordance with Haberl (2001) and Singh, et al (2010).

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[13] Mr. Aristotle has been a key informant for author Baka since 2009. Interviews were conducted on 3/16/09 and 6/21/10 and the survey was administered on 1/22/11.

The goal of the study is to compare the material and energy flows of Prosopis and Jatropha in Sattur taluk (Figure 1.1). It is unclear whether Jatropha and Prosopis can coexist on a plot given deep tap roots of both trees and invasive nature of Prosopis (Robbins 2001), which may lead to competition for water and nutrients (Tewari, Pasiecznik et al. 1993; Heller 1996). Further, Jatropha companies operating in the area first removed Prosopis before establishing Jatropha.[14] Thus, we assumed the entire area of Prosopis (16,573 ha) would be replaced with Jatropha.

Because of the initial land use impacts of biofuel production and the gestation period of Jatropha trees, we compared the Jatropha and Prosopis systems on a 20-year timeline, a common timeframe used in previous Jatropha LCA studies (Reinhardt, Gaertner et al. 2007; Whitaker and Heath 2008; Bailis and Baka 2010; Almeida, Achten et al. 2011). At present, there is still uncertainty on the maturity of Jatropha plants with literature estimates ranging from three to five years (Reinhardt, Gaertner et al. 2007; Brittain and Lutaladi 2010). We assumed a gestation period of four years. As Prosopis trees are already established in the region, we assumed no gestation period. However, once coppiced, regrowth takes three years.

We examined the "well to wheel" material and energy flows of the Prosopis and Jatropha systems. This entails wood gathering and combustion for the Prosopis system and seedling rearing in nurseries, land clearance, cultivation, seed harvesting, oil extraction

[14] Interviews with D. Aristotle, General Manager, Emami Biotech, 3/16/09 and 6/21/10 and survey 1/22/11.

and biodiesel production and use for the Jatropha system. We did not include infrastructures such as building and irrigation materials in our models.

Jatropha Modeling Assumptions

Modeling assumptions are derived from the Emami survey and a literature review. Detailed modeling assumptions are included as Appendix 1.3 while the main assumptions for each stage are highlighted below.

Nursery, Land Preparation and Cultivation

In accordance with Emami's current practices, Prosopis will need to be cleared before planting Jatropha. This requires the use of a JCB machine. Gypsum is then applied to level the pH balance of the soil but Emami acquires this from a fertilizer plant in the area where it is a manufacturing by-product. Thus, only the transport energy and not the manufacturing energy for gypsum production is included in the energy flows of the system. Finally, the land will be plowed twice using a diesel tractor.

We assumed seedling nurseries would be co-located at plantation sites and would require the same fertilizer, pesticide and irrigation applications that Emami used at their nursery (Appendix 1.3). The seedling gestation period is three months. We did not assume the use of polybags to raise seedlings as this is not Emami's current practice.

Regarding plantation cultivation practices, we assumed plant spacing of 4 by 1.5 meters, as per the Emami's practices. Based on current industry practices, we assumed annual fertilizer and pesticide application, as well as irrigation. At present, the fertilizer, pesticide and water needs of Jatropha are uncertain (Almeida, Achten et al. 2011). We used a mix of survey data and literature values to determine these parameters.

Based on Almeida, et al, (2011) we assumed annual NPK fertilization rates of 179 kg/ha, 58 kg/ha and 129 kg/ha, respectively.[15] Emami is not actively maintaining their plantation but applied 123.5 kg/ha of Diammonium Phosphate (DAP) / Potash fertilizer at their nursery. Regarding pesticide, Emami applied approximately 1 kg/ha/year of Endosulphate at their nursery. As literature values were inconclusive on pesticide usage, we assumed Emami's nursery practices would apply to Jatropha plantations. In accordance with Almeida, et al (2011), we assumed fertilizer and pesticide application for 20 years.

The water needs of Jatropha has been a contentious issue in the literature. One recent study estimated Jatropha requires 574 cubic meters (m3) of water per gigajoule (GJ) of biodiesel, the most of any biofuel feedstock reviewed in the study (Gerbens-Lennes, Hoeskstra et al. 2009).[16] Other authors critiqued these findings both in terms of the non-peer reviewed data sources used and methodology applied (Maes, Achten et al. 2009).

[15] Almeida, et al, 2011 gathered data through Jatropha entrepreneur surveys (count not given in paper or supplemental materials), observation of 25 plantations across India and literature reviews.

[16] This figure includes water for irrigation and processing. The authors do not breakdown water requirements by process.

Again following Almeida, et al, (2011) we assumed annual rainfall requirements of 1,500 mm per year ($15*10^6$ L/ha).[17]

Using data on the average monthly rainfall in Virudhunagar District (Virudhunagar District Collector 2009), we calculated irrigation requirements as the difference between water needs and rainfall. On this basis, we estimate Jatropha requires approximately 6.7 million L/ha/yr. We assumed irrigation for the first three years, in accordance with Whitaker and Heath (2008). Almeida, et al, (2011) found a high degree of variance in current irrigation practices in their study and we felt irrigation for the initial three years was a reasonable assumption based on discussions with Emami and research at the Tamil Nadu Agricultural University concerning the best practices of Jatropha cultivation (Paramathma 2007).

Biodiesel Processing

We assume a combined crushing unit and transesterification unit would be established in the town of Sattur, the largest urban center in the talluk. We modeled a 500 kg of seeds/hour mechanical extraction crushing facility based on ACS's data and modeled a 100,000 tonne per year biodiesel unit based on specifications in the Planning Commission report (2003) . We assumed an extraction efficiency of 22.4%, the average value for mechanical extraction from the literature (Reinhardt, Gaertner et al. 2007; Gmuender, Zah et al. 2009; Sharma and Singh 2009; Brittain and Lutaladi 2010). Further,

[17] We also considered the impacts of no irrigation or chemical inputs in our modeling results.

we modeled a transesterification unit using a methanol alcohol and a potassium hydroxide catalyst (Government of India 2003).

Finally, in accordance with India's current biodiesel policy guidelines (Government of India 2005), we assume all biodiesel manufactured at the unit will be exported out of the taluk to the nearest oil marketing center (OMC). The closest OMC is in Karur in the north-central portion of the state, 213 km from Sattur.

By-Products

Following LCA convention, residual materials of the production process that can be put to productive use can be considered by-products of the system. The main by-products resulting from the Jatropha system are Prosopis uprootings from land clearance, seedcake from oil extraction and glycerine from transesterification. We assumed the uprooted Prosopis would be a by-product for other industries within the system in accordance with current Prosopis usage practices.

As a market for Jatropha and its by-products is yet to emerge, we modeled four possible scenarios for Jatropha by-product usage as described below. Additionally, we modeled a base case scenario in which no irrigation or chemical inputs were applied.

Scenarios

<u>Scenario 0 (S0):</u>

We assumed no irrigation or chemical inputs and no by-product usage.

Scenario 1 (S1):

We assumed all by-products would be discarded.

Scenario 2 (S2):

We assumed the Prosopis uprooting biomass would be used for energy production within Sattur in the same fashion as the Prosopis energy economy currently operates.

Scenario 3 (S3):

We assumed only Jatropha by-products would be used. In accordance with Almeida, et al (2011) we assumed the seedcake would be anaerobically digested to produce biogas and fertilizer for use within the Sattur economy. Further, we assumed the glycerine by-product would be used in the chemicals and pharmaceutical industry. As no such industries exist in Sattur, we assumed the glycerine by-product would be exported to the chemical factories and international port located at Tuticorin.

Scenario 4 (S4):

We assumed both Prosopis and Jatropha by-products would be used in the manners described in scenarios 2 and 3 above.

Wastes

The Jatropha system may also result in biomass from pruning and seed husks from oil extraction. However, there is currently no alternative use of these products nor do the majority of Jatropha LCAs consider these products.[18] Further, the amount of pruning

[18] Whitaker and Heath (2008) assume pruning biomass is used for electricity generation but their biomass estimates are based on an interview with an Indian Oil Corporation executive and not actual field trials. Thus, these estimates are highly uncertain. Various

biomass is highly uncertain as only one LCA estimated this figure on the basis of an interview with an Indian Oil Corporation executive (Whitaker and Heath 2008). Thus, we do not estimate the amount of pruning biomass in the model. Husk biomass is a function of the mass of a Jatropha fruit. We assume the husk biomass is discarded from the system.

Prosopis Modeling Assumptions

Remote sensing techniques were used to estimate the extent of Prosopis coverage in the taluk. Conversion and efficiency estimates were obtained through surveys and through literature reviews. Calorific values for Prosopis components were obtained through lab testing. The detailed modeling assumptions are included as Appendix 4. The remote sensing and biomass estimates of Prosopis are described below.

Remote Sensing

We estimated the current area of Prosopis in Sattur through a comparison of three seasonally differentiated LANDSAT 7 satellite images of the region. Images from November 2009, March 2010 and January 2011 were used as these were the most recent images available with minimal cloud cover. The spectral profile for Prosopis was determined through ground truthing points obtained in the course of fieldwork. Based on the analysis, we estimate approximately 16,573 ha of Prosopis in Sattur, which is just

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LCAs (Whitaker and Heath, 2008, Reinhardt, et al, 2007) have considered using the seed husks as an electricity feedstock but Almeida, et al, (2011) did not find widespread use of the husks in their data gathering.

over 36% of the total geographic area of the taluk (Table 1.3). The image classifications are included as Appendix 1.2.

The sizable reduction in Prosopis area between 2009 and 2010 is likely the product of government policy. The Virudhunagar District Collector at the time, Ms. Sigy Thomas Vaidhayan, initiated numerous projects to eradicate Prosopis. She left office in June 2010 and according to interviews with government officials, Prosopis eradication programs were stopped.[19] This may in part explain the increase in Prosopis area between 2010 and 2011.

Table 1.3: Estimated Prosopis Area, Sattur Taluk

Image Date	**Prosopis Area**	**Total Area**	**% Prosopis**	**% Change**
	ha	ha	%	%
11/29/09	20,740	45,749	45.3%	
3/21/10	11,606	45,749	25.4%	-44.0%
1/19/11	17,374	45,749	38.0%	49.7%
AVERAGE	**16,573**	**45,749**	**36.2%**	

Prosopis Biomass

Based on the field experiments of Bailis and McCarthy (2011) in Rajapalayam taluk, Tamil Nadu (Figure 1.1) we assumed 16.5 tonnes of Prosopis above-ground biomass per hectare. This estimate excludes leaf litter.

[19] Interviews with Srivilliputtur Business Development Office (BDO) clerks, 9/23/10 and Virudhunagar BDO and District Rural Development Agency (DRDA) officials, 9/30/10.

Results

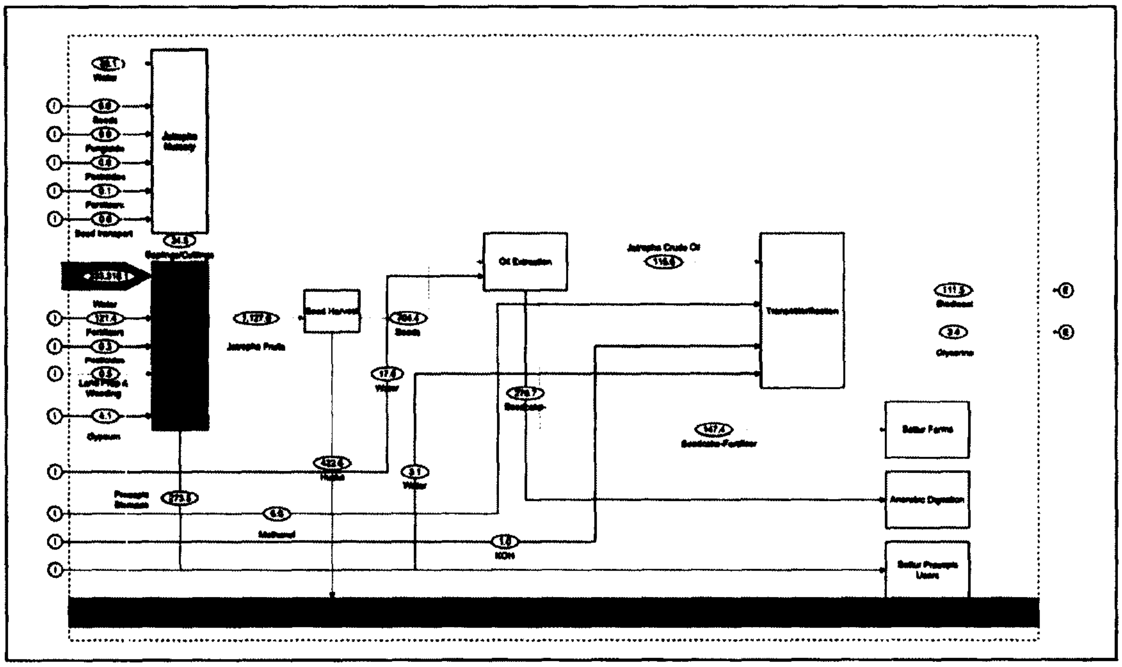
Jatropha Results

MFA

Over the 20-year lifespan, approximately 335.8 million tonnes of materials flow through the Jatropha system. Nearly 333.5 million tonnes of these material flows (99.3% of total material flows) are inputs to the system. Water for irrigation purposes during the cultivation stage accounts for 99.3% of these material flows (333.3 million tonnes). As a result, the cultivation stage is the most material-intensive stage comprising 99.3% of material flows.

Following water, the main material flows are the Jatropha seeds, by-products and Prosopis uprootings resulting from biodiesel production: seeds (704.1 thousand tonnes), seedcake (589.4 thousand tonnes) and seed husks (422.6 thousand tonnes), Prosopis uprootings (273.5 thousand tonnes). Lastly, Jatropha biodiesel accounts for only 0.03% of all material flows (111.5 thousand tonnes). The material flows for each production stage are summarized below in Figure 1.3 and the individual material values for each stage are included as Appendix 1.5.

Figure 1.3: Jatropha MFA, 20-year Lifespan



An aggregate production-stage level summary of inputs, outputs, potential by-products, direct material extraction and wastes is included in Table 1.4. The cultivation stage accounts for nearly 82% of all material flows followed by the harvest stage (8.8%) and the oil extraction stage (5.7%).

Table 1.4: Jatropha System Aggregate Material Flows by Production Stage, 20-year Lifespan

Stage	Inputs	Outputs[1]	By-Products	Domestic Extraction	Waste	TOTAL	Percentage
	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs	%
Nursery	29.2	34.5	-	-	-	63.7	0.0%
Land Prep	4.6	-	-	273.5	-	278.1	0.1%
Cultivation	333,439.8	-	-	-	-	333,439.8	99.3%
Harvest	0.1	704.4	-	-	422.6	1,127.0	0.3%
Oil Extraction	17.6	115.0	589.4	-	-	722.0	0.2%
Transesterification	10.1	111.5	3.4	-	-	125.1	0.0%
TOTAL	**333,501.4**	**965.3**	**592.9**	**273.5**	**422.6**	**335,755.7**	**100.0%**

Note:
1.We do not include standing biomass of Jatropha trees as an output as it is not used for biodiesel production. However, this stock would be significant in a carbon accounting of the biodiesel system.

Additionally, nearly all of the materials flowing through the system are extracted or are circulating locally (99.9%). This is driven by the assumption that irrigation water will originate from within Sattur as irrigation water is pumped from ground water within the taluk. As per India's current biodiesel guidelines, the resultant Jatropha biodiesel will be exported from the system.

Table 1.5: Origin and Destination of Jatropha System Material Flows, 20-year Lifespan

	Imports	**Local Extraction or Use**	**Exports**	**TOTAL**
	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs
Inputs	132.9	333,368.6	-	333,501.4
Outputs	-	853.8	111.5	965.3
Domestic Extraction	-	273.5	-	273.5
By-Products	-	589.4	3.4	592.9
Wastes	-	422.6	-	422.6
TOTAL	**132.9**	**335,507.9**	**115.0**	**335,755.7**
TOTAL Percentage	**0.0%**	**99.9%**	**0.0%**	**100.0%**

The material intensity of the Jatropha system can be estimated by comparing outputs and inputs from production. This will depend on how, if at all, by-products are used. Table 1.6 below calculates the output input ratios for the five scenarios considered in the study.

The output to input ratio for the base case scenario (S0), which considers no irrigation or chemical inputs, is 29.8. Because of the probable large water demand of the Jatropha production system, the output to input ratio is quite low for all remaining scenarios ranging from 0.003 units of output per unit of input in S1 to 0.005 units of output per unit of input in S3 and S4 (column 4, Table 1.6). Alternatively framed, the Jatropha system requires nearly 8 to 10 units of input per unit of output, depending on by-product usage (column 5, Table 1.6).

Table 1.6: Material Intensity of Jatropha System, 20-year Lifespan

Scenario	**Inputs**	**Outputs**	**By-Products & DE**	**Output:Input**	**Input:Output**
	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs	ratio	ratio
	[1]	[2]	[3]	[5]=[2]+[3]/[1]	[4]=[1]/[2]+[3]
S0	32.4	965.3		29.799	0.0
S1	333,501.4	965.3		0.003	345.5
S2	333,501.4	965.3	273.5	0.004	269.2
S3	333,501.4	965.3	592.9	0.005	214.0
S4	333,501.4	965.3	866.3	0.005	182.1

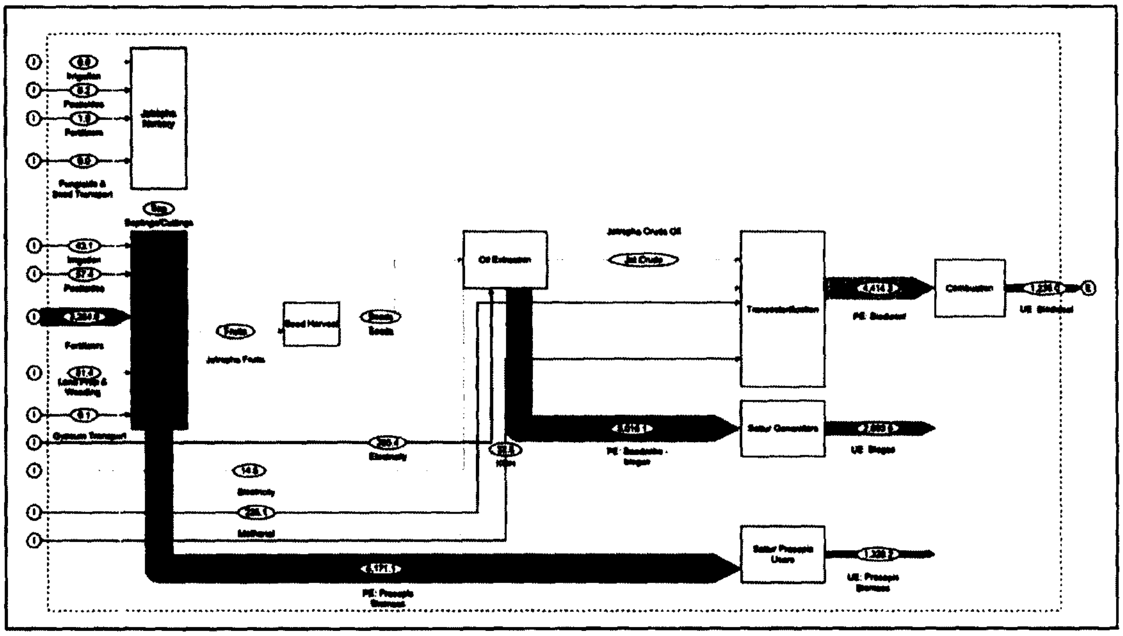
Note:
1. DE is domestic extraction, which in this model refers to the mass of Prosopis uprootings resulting from land clearance.

EFA

Approximately 18.5 petajoules (PJ) of energy flow through the Jatropha system over the 20-year lifespan. Energy inputs account for approximately 3.9 PJ. The cultivation stage is the most energy-intensive stage accounting for almost 88.9% (3.4 PJ) of all energy inputs. The main input for this stage is chemical fertilizer (3.3 PJ), which accounts for 95.3% of all input flows.

Unlike the material flow accounting, energy outputs (4.4 PJ) slightly exceed energy inputs (3.9 PJ) due to the energy density of liquid fuels. If used for energy production, the Prosopis uprootings would be the largest energy flow in the system, representing 5.2 PJ (28% of all energy flows). If used to produce biogas, Jatropha seedcake would be the second most substantial flow contributing 5.0 PJ or 28% of all flows. Jatropha biodiesel (4.4 PJ) accounts for approximately 23.9% of all energy flows. The oil extraction and transesterification stages account for nearly 2/3rd of total energy flows through the system with each stage contributing 29.3% and 24.5%, respectively. The cultivation stage, dominated by chemical fertilizer production and application accounts for 18.6% of energy flows. The land preparation stage represents just over 28% of energy flows because of the primary energy content of the Prosopis uprootings. Figure 1.4 and Table 1.7 below depicts the circulation of energy through the Jatropha production system. The individual energy flows for each material or activity are included as Appendix 1.6.

Figure 1.4: Jatropha EFA, 20-year Lifespan



Notes:
PE: primary energy.
UE: useful energy.
Assumes Prosopis uprooting biomass circulated in Sattur economy.
Assumes all biodiesel produced exported to nearest Oil Marketing Company (OMC) in Karur, Tamil Nadu as per India's biodiesel purchase policy.

Table 1.7: Jatropha System Aggregate Energy Flows by Production Stage, 20-year Lifespan

Stage	Inputs	Outputs	By-Products	Domestic Extraction	TOTAL	Percentage
	TJ/ 20-yrs	TJ/ 20-yrs	TJ/ 20-yrs	TJ/ 20-yrs	TJ/ 20-yrs	%
Nursery	2.1	-	-	-	2.1	0.0%
Land Prep	22.1	-	-	5,171.1	5,193.3	28.1%
Cultivation	3,423.9	-	-	-	3,423.9	18.6%
Harvest	2.5	-	-	-	2.5	0.0%
Oil Extraction	385.4	-	5,016.1	-	5,401.5	29.3%
Transesterification	14.5	4,414.3	-	-	4,428.7	24.0%
TOTAL	**3,850.5**	**4,414.3**	**5,016.1**	**5,171.1**	**18,452.0**	**100.0%**

Note: Domestic extraction and output values are primary energy values.

If grown in rainfed conditions without any chemical inputs, the EROI of the Jatropha system is 10.4 (Table 1.8, S0). Depending on how, if at all, by-products are used, the

EROI of the Jatropha system decreases to 1.1 to 3.8 (Table 1.8). This means more energy is provided by the Jatropha system than is required to produce this energy. When by-products are not put to an energetic use, energy outputs are approximately equal to energy inputs (S1, Table 1.8). However, when the Prosopis uprootings and Jatropha seedcake are utilized, energy outputs, by-products and domestic extraction are over 2.4 times energy inputs (Table 1.8, S4). Thus, similar to previous Jatropha LCAs (Whitaker and Heath 2008; Almeida, Achten et al. 2011), by-products are a main driver of this system.

Table 1.8: EROI of Jatropha System, 20-year Lifespan

Scenario	Inputs	Outputs	By-Products	Domestic Extraction	EROI
	TJ/ 20-yrs	TJ/ 20-yrs	TJ/ 20-yrs	TJ/ 20-yrs	
	[1]	[2]	[3]	[4]	[5]=[2]-[4]/[1]
S0	424.5	4,414.3			10.4
S1	3,850.5	4,414.3			1.1
S2	3,850.5	4,414.3		5,171.1	2.5
S3	3,850.5	4,414.3	5,016.1		2.4
S4	3,850.5	4,414.3	5,016.1	5,171.1	3.8

Evaluating the useful energy provided by the Jatropha system is a second perspective on the energy efficiency of the system.[20] Regarding the scenarios evaluated for the Jatropha system, primary energy is the energy content of Jatropha biodiesel plus the energy content of by-products prior to combustion. As shown below in Table 1.9, by-product usage increases useful energy in all scenarios. The efficiency of the system, calculated as

[20] Useful energy is the amount of primary energy remaining after product transformation delivered for end use consumption. The difference between primary energy and useful energy is waste energy.

the ratio between useful and primary energy, increases with by-product usage except between scenarios S1 to S2 and S3 to S4. This is because the Prosopis system is estimated to have a slightly lower thermal efficiency rate (25.6%, Prosopis results section) compared to the thermal efficiency of biodiesel (28% as per (Agarwal and Agarwal 2007).

Excluding by-product usage, the Jatropha system converts 28% of the primary energy contained in Jatropha oil to useful energy (scenarios S0 and S1). Utilizing Prosopis uprooting biomass for energy purposes nearly doubles useful energy but reduces energy efficiency to 26.8% (scenario S2). Utilizing only Jatropha by-products triples useful energy and increases efficiency to 41.7% (scenario S3). Utilizing both Prosopis and Jatropha by-products (scenario S4) results in a five-fold increase in useful energy but reduces efficiency to 36%.

It is also crucial to examine where the useful energy will be consumed as this will impact energy provision within Sattur taluk. As per India's current biodiesel guidelines (Government of India 2005), all biodiesel produced in Sattur taluk would have to be exported out of the system to the nearest oil marketing company in Karur, Tamil Nadu for blending and redistribution. It is uncertain what quantity, if any, would be returned to Sattur. Therefore, it is assumed all biodiesel useful energy is exported from Sattur.

As result, the only useful energy provided by the Jatropha system consumed within Sattur will be the useful energy provided from by-product consumption. We assume the

Prosopis uprootings will be used in the same manner as the current Prosopis system (discussed in the Prosopis results section). However, this can be viewed as a one-time endowment to the Sattur energy system as the resource will be non-existent after the Jatropha system is established. Further, we assumed biogas produced from the seedcake would be consumed locally within the Sattur economy. As summarized in Table 1.9, between 31.5 and 100% of the useful energy resulting from the Jatropha system will be exported from Sattur taluk.

Table 1.9: Energy Efficiency of Jatropha System, 20-year Lifespan

Scenario	Primary Energy	Useful Energy	Waste Energy	Useful Energy Percentage	Energy Exports	Export Energy Percentage
	TJ/ 20-yrs	TJ/ 20-yrs	TJ/ 20-yrs	%	TJ/ 20-yrs	%
	[1]	[2]	[3]=[1]-[2]	[4]	[5]	[6]=[5]/[2]
S0	4,414.3	1,236.0	3,178.3	28.0%	1,236.0	100.0%
S1	4,414.3	1,236.0	3,178.3	28.0%	1,236.0	100.0%
S2	9,586.4	2,565.2	7,021.2	26.8%	1,814.2	70.7%
S3	9,430.4	3,929.6	5,500.7	41.7%	1,236.0	31.5%
S4	14,602.5	5,258.9	9,343.6	36.0%	3,050.2	58.0%

Note: S0 is identical to S1 because S0 differs only in terms of energy inputs to the system.

Prosopis Results

In total, the eight Prosopis user groups surveyed in this study consume approximately 162,000 tonnes of Prosopis on an annual basis. Approximately 77% of the wood is purchased from wood merchants, 14% is gathered by villagers and sold to industry and close to 9% is self-collected. The consumption by user group is detailed below.

Consumption by User Group

Power Plant

The 10-megawatt (MW) biomass power plant operated by Dubai-based ETA opened in Periyampatti village (village 38, Figure 1.2) in May 2009. It is the only such power plant in Sattur taluk. The plant uses 320 tonnes of wood per day, 90% (288 tonnes) of which is Prosopis. The remaining feedstocks are waste wood from the local matchbox factories and Kerala. On average, the power plant operates 310 days per year, which equates to 89.3 thousand tonnes of Prosopis per year. As such, the power plant is the largest user of Prosopis in the taluk using almost three times more wood than the paper industry, the second largest user. The power plant procures nearly 78.1% of its Prosopis from wood merchants and the remainder (21.9%) from local villagers. The power plant uses 1MW of capacity internally. The remaining 90% of electricity generated is sold to the Tamil Nadu electricity grid and is thus considered an export from the system for modeling purposes.

Paper Factories

We surveyed two paperboard manufacturing companies in the taluk as well as a gypsum factory that manufactures plaster of Paris. Both industries use Prosopis as a feedstock for their factory boilers. Collectively, the five paper factories use 92.6 thousand tonnes of Prosopis per day, which equates to 33.8 thousand tonnes of wood per year. The paper industry is the second largest user of Prosopis in the taluk. The paper and gypsum factories procure approximately 92.6% of their Prosopis needs from local wood merchants and 6.4% by buying directly from local villagers.

Brick Making

Brick makers use Prosopis to fire brick kilns. The main brick production region is in the southwest corner of the taluk, including survey villages 21, 24 and 29 (Figure 1.2). Bricks are fired outside in kilns such as the one shown below in Picture 1.1. A typical brick maker uses about 0.34 tonnes of Prosopis per day (123 tonnes/year), all of which is procured from local merchants. With an estimated 125 brick makers in the taluk, annual Prosopis usage is estimated at 15.4 thousand tonnes per year. Brick makers also use a small portion of charcoal for brick firing. Based on surveys, we estimate brick makers use approximately 230 tonnes of charcoal per year, all of which is procured from local charcoal merchants.

Picture 1.1: Typical Brick Kiln, Sattur Taluk

Charcoal

Prosopis is the primary wood feedstock used for charcoal production in Sattur taluk. Charcoal production rotates throughout the taluk. We surveyed producers in survey villages 12, 24 and 37 (Figure 1.2). A typical charcoal pile is shown below in Picture 1.2. Based on the survey data, an average charcoal maker uses about 0.26 tonnes of Propsopis per day (95.3 tonnes/year). With an estimated 121 charcoal makers in the taluk, this equates to 11.5 thousand tonnes of Prosopis per year circulating through the charcoal industry. The charcoal makers acquire self-procure all of their wood needs, typically within a 5-10 kilometer (km) radius of their production site.

We estimate annual charcoal production of 3.5 thousand tonnes per year in Sattur. Approximately 28% (968 tonnes) is sold within Sattur to brick makers and eateries and the remainder is sold outside the taluk. Interestingly, some of these traders reportedly sell the charcoal in Mumbai, Chennai and Hyderabad based on interviews with Sattur charcoal makers.

Picture 1.2: Typical Charcoal Pile, Sattur Taluk

Rural Households

Based on the survey data, we estimate that 56% of households in Sattur taluk currently use Prosopis as a fuelwood. Further, these households use approximately 0.93 kg of wood per day (0.34 tonnes/year). With 41,087 households in the taluk (Government of India 2001), this equates to 7.8 thousand tonnes of wood per year circulating through rural households. In terms of procurement, approximately 35% of households gather their fuelwood locally while the remainder (65%) purchase fuelwood from local wood merchants.

Eateries

Tea stalls and small-scale eateries (typically referred to as hotels) use Prosopis for boiling water and for cooking. We surveyed a diverse mix of establishments serving between 10-15 to 700 customers per day. The average daily Prosopis wood use for one eatery is just over 81 kg per day (30 tonnes/year). There was an average of 1.4 hotels and tea stalls in the sample villages indicating approximately 76 such establishments in the taluk as a whole. Thus, nearly 2.3 thousand tonnes of Prosopis is circulating through the eateries industry per year. Establishment owners indicated procuring nearly 96.7% of their supply from local wood merchants, about 2.7% through contracting with cutting crews and the remainder (0.6%) through self-procurement.

Match Factories

Match factories use Prosopis to boil glue and wax for affixing the ignition tips to matches.[21] While there are both mechanized and non-mechanized factories, we estimate there are currently 151 non-mechanized factories and 9 mechanized factories in the taluk (2.7 factories per village). We estimate a non-mechanical factory uses about 19 kg of Prosopis per day (7 tonnes/yr) while a mechanical factory uses just over 75 kg per day

[21] Wood wastes from the neighboring state of Kerala are used for the match sticks.

(27.5 tonnes/yr). In total, approximately 1.3 thousand tonnes of Prosopis are circulating through the match industry per year. Of this amount, about 96.3% is procured from local merchants, 3.1% is self-procured and the remainder (0.6%) is obtained from local villagers who gather the wood and sell it directly to the factories.

Oil Mills

Finally, the sole oil mill in the taluk that produces paraffin wax uses Prosopis in its boilers. On a daily basis, the mill uses just over 2 tonnes of Prosopis (750 tonnes/year). The mill purchases all of its Prosopis needs from local villagers.

Table 1.10 below summarizes the Prosopis wood usage and procurement methods for each of the industries.

Table 1.10: Prosopis Usage and Procurement by Industry

	Usage			*Procurement*			
Industry	**Industries in Taluk[1]**	**Annual Use**	**Usage Percentage**	**Self-Procure**	**Merchants**	**Villagers**	**Other[2]**
	#	ktonnes/yr	%	%	%	%	%
power plant	1	89.3	55.1%	0.0%	78.1%	21.9%	0.0%
paper mills	5	33.8	20.8%	0.0%	92.6%	7.4%	0.0%
brick making	125	15.4	9.5%	0.0%	100.0%	0.0%	0.0%
charcoal	121	11.5	7.1%	100.0%	0.0%	0.0%	0.0%
rural homes	23,114	7.8	4.8%	34.6%	65.4%	0.0%	0.0%
eateries	76	2.3	1.4%	0.6%	96.7%	0.0%	2.7%
match factories	151	1.3	0.8%	3.1%	96.3%	0.6%	0.0%
oil mills	1	0.8	0.5%	0.0%	0.0%	100.0%	0.0%
TOTAL[3]	**23,594**	**162.1**	**100.0%**	**8.8%**	**77.1%**	**14.0%**	**0.0%**

Notes:
1. Rural homes refer to the number of rural homes using Prosopis fuelwood in the taluk.
2. One Eatery surveyed hired cutting crews to procure Prosopis stocks.

Wood Traders

As can be seen from Table 1.10, wood merchants play a substantial role in the Sattur Prosopis economy by supplying just over 77% of Prosopis needs to users. The merchants obtain this wood from coppicing trees within the taluk as well as importing Prosopis from other areas.

There are both large-scale and small-scale merchants operating in the taluk. The four large-scale merchants operate at a central trading post outside of Sattur city (Figure 1.2). Collectively, they are trading an average of almost 168 tonnes of wood per day (61.2 thousand tonnes/yr). They procure Prosopis through local extraction and through importing from outside the taluk. The merchants obtain approximately 17% of the wood within Sattur by contracting with smaller traders[22] or by purchasing from local villagers. The remaining wood is imported to Sattur, typically from within a 25 to 60 km radius. In addition to supplying wood to users within the taluk, the merchants also export wood throughout the state, primarily to the dying factories in Tirupur (northern Tamil Nadu), to paper and brick factories in the neighboring taluk of Sivakasi (Fig 1), to tea plantations in the north of the state, and to other biomass power plants in the state.

The large-scale traders reported selling an average of 25.1 thousand tonnes per year of Prosopis within Sattur. As the various Prosopis users reported obtaining approximately

[22] There appears to be a great deal of variance with sub-contracting practices. One of the large-scale traders interviewed contracts with 142 local traders and trades approximately 60 tonnes of wood per day while the second large-scale trader interviewed contracts with 8 local traders and trades about 30 tonnes of wood per day.

77% (125 thousand tonnes per year) of Prosopis from wood merchants (Table 1.10), we assumed small-scale wood traders (ie. all wood traders not operating at the main post nearby Sattur town) provide the difference between wood purchased from merchants and wood supplied by large-scale traders (99.1 thousand tonnes per year).

Unfortunately, we had a challenging time finding such small-scale merchants to survey. In instances where we found such merchants, they were reluctant to talk with us. Therefore, we assume the small-scale merchants operate in a similar fashion to the large-scale merchants, meaning they obtain 16.9% of the Prosopis stock provided to Sattur users from local extraction and import the remainder from regions outside Sattur. We assumed this because the three largest Prosopis users (power plant, paper and bricks), which account for 85.4% of total usage, are located in the southwestern portion of the taluk, where Prosopis coverage is the least dense (Appendix 1.2).[23] Table 1.11 summarizes wood trading activity within Sattur.

[23] Additional remote sensing work will be performed to improve this estimate.

Table 1.11: Summary of Prosopis Wood Trading Activity, Sattur Taluk

		Merchant Category		
		Large-scale	**Small-scale**	**TOTAL**
		ktonnes/yr	ktonnes/yr	ktonnes/yr
procurement	within Sattur	10.3	16.8	27.2
	imports	50.9	83.0	133.9
	TOTAL	61.2	99.9	161.1
	Local collection percentage	16.9%	16.9%	16.9%
sales	within Sattur	25.1	99.9	125.0
	exports	36.1	unknown	unknown
	TOTAL	61.2	unknown	unknown
	Local sales percentage	41.0%	unknown	unknown

Sources:
Large-scale merchants: surveys.
Small-scale merchants: estimated.

By-Products and Waste

Prosopis combustion can generate ash and charcoal as wastes/by-products.[24] All groups but charcoal makers reported ash generation and only eateries reported charcoal waste generation. We estimated the amount of ash generation based on the Prosopis calorific analysis. Through complete combustion of Prosopis, 2% of ash by weight remains. As result, Prosopis use in Sattur generates just over 3 thousand tonnes of ash per year. Based

[24] Charcoal results from pouring water on the wood fire. If left to self-extinguish, only ash will result.

on surveys with eateries, approximately 114 tonnes of charcoal is generated per year (Table 1.12).

The power plant, the largest generator of ash, exports the ash to brick makers outside Sattur taluk. Aside from rural homes, the other Prosopis users reported using about 50% of ash generation for local purposes such as agricultural compost, dish washing and road repair. The remaining ash was discarded. Rural homes reported using about 80% of ash for local uses and discarding 20% of ash. Eateries used 100% of charcoal generation as a feedstock for heating tea.

Ash and charcoal generation, reuse and disposal are summarized below in Table 1.12.

Table 1.12: Annual Prosopis By-Product Generation, Reuse and Disposal

	By-Product			*Disposal*				
Industry	**Ash**	**Charcoal**	**TOTAL**	**Local Usage**	**Exports**	**Waste**	**TOTAL**	**Uses**
	ktonnes/yr	ktonnes/yr	ktonnes/yr	ktonnes/yr	ktonnes/yr	ktonnes/yr	ktonnes/yr	
power plant	1.8	-	1.8	-	1.8	-	1.8	sell to brick makers outside system (100%)
paper mills	0.7	-	0.7	0.3	-	0.3	0.7	compost (50%), waste (50%)
brick making	0.3	-	0.3	0.2	-	0.2	0.3	local use (50%) [road repair, covering load of bricks before firing], waste (50%)
charcoal	NA	NA	-	-	-	-	-	
rural homes	0.2	-	0.2	0.1	-	0.0	0.2	local use (80%) [dish washing, compost], waste (20%)
eateries	0.0	0.1	0.2	0.1	-	0.0	0.2	ash: local use (50%) [dish washing, compost], waste (50%) charcoal: warming tea (100%)
match factories	0.0	-	0.0	0.0	-	0.0	0.0	compost (50%), waste (50%)
oil mills	0.0	-	0.0	0.0	-	0.0	0.0	compost (50%), waste (50%)
TOTAL	**3.0**	**0.1**	**3.1**	**0.8**	**1.8**	**0.6**	**3.1**	

MEFA Results

MFA

On an annual basis, we estimate approximately 198.2 thousand tonnes of Prosopis circulates through the economy. Over the 20-year lifespan, this equates to 3.9 million tonnes of Prosopis. These flows result in nearly 63 thousand tonnes of ash, 15 thousand tonnes of which are put to local use, nearly 36 thousand tonnes of which are exported from Sattur with the remainder being discarded. The material flows are summarized below in Table 1.13 and Figure 1.5.

Table 1.13: Prosopis Material Flows, 20-year Lifespan

	Material Flows		*By-Products*			
Industry	**Prosopis Wood**	**Prosopis Wood**	**Local Usage**	**Exports**	**Waste**	**TOTAL**
	ktonnes/yr	ktonnes /20-yrs	ktonnes /20-yrs	ktonnes /20-yrs	ktonnes /20-yrs	ktonnes /20-yrs
	[1]	[2]=[1]*20	[3]	[4]	[5]	[6]=[3]+[4]+[5]
power plant	89.3	1,785.6	-	35.8	-	35.8
paper mills	33.8	675.8	6.8	-	6.8	13.5
brick making	15.4	308.3	3.1	-	3.1	6.2
charcoal	11.5	230.0	NA	NA	NA	NA
rural homes	7.8	156.2	2.5	-	0.6	3.1
eateries	2.3	45.1	2.7	-	0.5	3.2
match factories	1.3	25.9	0.3	-	0.3	0.5
oil mills	0.8	15.0	0.2	-	0.2	0.3
wood traders[1]	36.1	721.9	NA	NA	NA	NA
TOTAL	**198.2**	**3,963.6**	**15.5**	**35.8**	**11.4**	**62.7**

Note:

1. To avoid double counting, the wood trader Prosopis flows is the amount of Prosopis imported or cut by the traders not sold to local users (ie. the amount of wood exported by large traders, Table 1.11).

Figure 1.5: Prosopis MFA, 20-year Lifespan

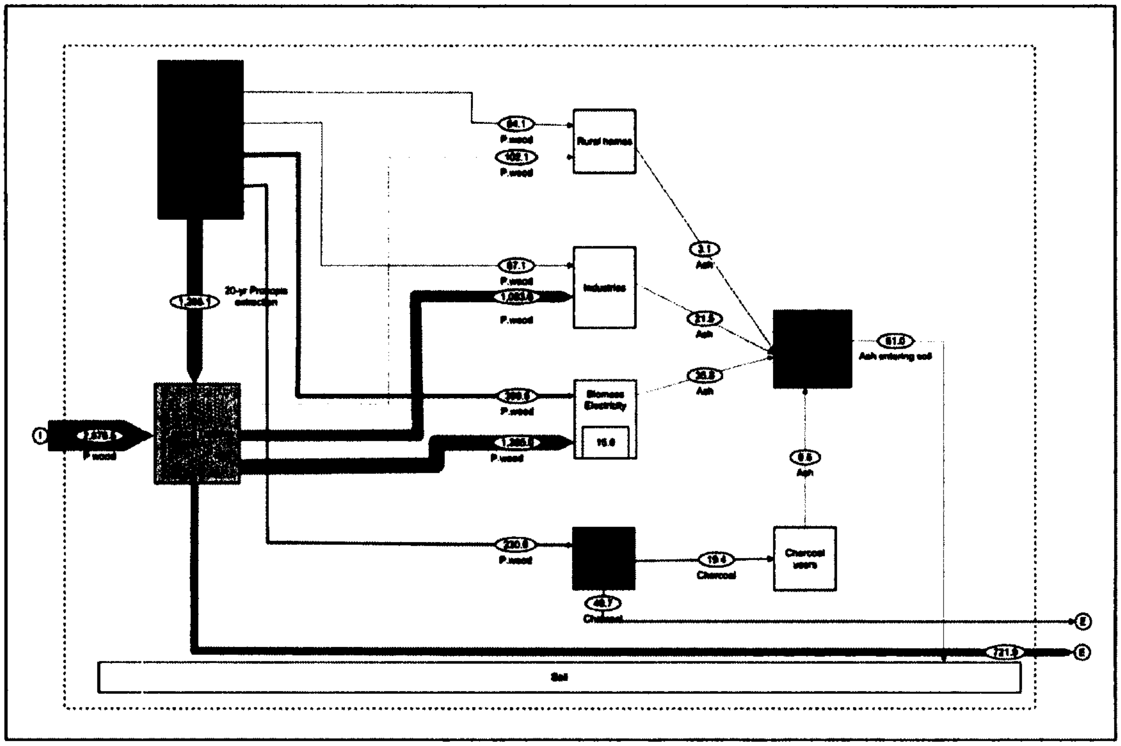


Table 1.14 arranges the Prosopis wood material flows into imports, local extraction and exports. The total in Table 21 differs from the total in Table 1.13 because it presents both wood imports/local extraction and exports of wood traders. As wood imports and local extraction equal local sales and exports, Table 1.14 essentially double counts wood exports. However, for illustration purposes, all three categories are presented. We estimate approximately 2.7 million tonnes of Prosopis are imported over a 20-year period while around 1.3 million tonnes will be locally extracted. Nearly 722 thousand tonnes will be exported.

Table 1.14: Prosopis Imports, Local Extraction and Exports, 20-year Lifespan

	Imports	**Local Extraction**	**Exports**	**TOTAL**
	ktonnes /20-yrs	ktonnes /20-yrs	ktonnes /20-yrs	ktonnes /20-yrs
power plant	-	390.6	-	390.6
paper mills	-	49.7	-	49.7
brick making	-	-	-	-
charcoal	-	230.0	-	230.0
rural homes	-	54.1	-	54.1
eateries	-	1.5	-	1.5
match factories	-	1.0	-	1.0
oil mills	-	15.0	-	15.0
wood traders	2,678.5	543.3	721.9	3,943.7
TOTAL	**2,678.5**	**1,285.1**	**721.9**	**4,685.5**
TOTAL %	**57.2%**	**27.4%**	**15.4%**	**100.0%**

Note: The total in Table 1.14 does not equal the total in Table 1.13 because it includes wood trader exports. In the model, wood extraction plus imports equal wood exports and local sales. Thus, Table 1.14 essentially double counts wood exports.

Figure 1.6: Prosopis EFA, 20-year Lifespan

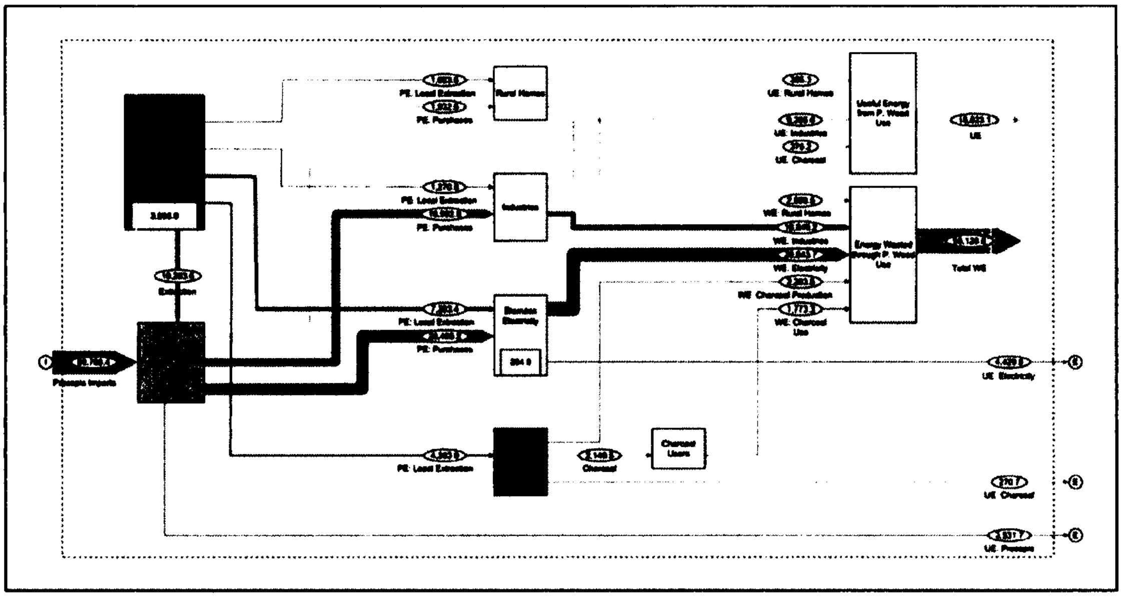


Table 1.15 estimates the material intensity of the Prosopis system. The only input to the system is the diesel fuel used to circulate the wood and to fire Prosopis at the power plant. Outputs in the table is the total amount of wood circulating in the economy from Table 1.13 and by-products are the total amount of ash and charcoal put to productive use (ie. the sum of columns 3 and 4 in Table 1.13). We estimate each tonne of input yields over 811 tonnes of output in the Prosopis system. Alternatively framed, each tonne of output requires 0.001 tonnes of input.

Table 1.15: Material Intensity of Prosopis System, 20-year Lifespan

Inputs	Outputs	By-Products	Output: Input	Input: Output
ktonnes /20-yrs	ktonnes /20-yrs	ktonnes /20-yrs	ratio	ratio
[1]	[2]	[3]	[4]=[2]+[3]/[1]	[5]=[1]/[2]+[3]
4.98	3,963.6	51.3	807.0	0.0

EFA

In terms of energy flows, we estimate approximately 4 PJ of primary energy from Prosopis wood is flowing through the system on an annual basis, which results in 72.8 PJ over 20 years. This total also includes transport energy required for local extraction of Prosopis, Prosopis imports and exports and the charcoal export energy.[25] Based on combustion efficiencies (Appendix 1.4), this results in 18.8 PJ of useful energy over the 20-year period and 56.1 PJ of waste energy. Thus, the system is 25.9% efficient (ratio of useful to primary energy).

Table 1.16: Prosopis Energy Flows, 20-year Lifespan

	Energy Flows					
Industry	**Primary Energy**	**Primary Energy**	**Combustion Efficiency**[1]	**Useful Energy**	**Waste Energy**	**Useful Energy Exports**
	TJ/yr	TJ/20-yrs	%	TJ/20-yrs	TJ/20-yrs	TJ/20-yrs
	[1]	[2]=[1]*20	[3]	[4]=[2]*[3]	[5]=[2]-[4]	[6]
power plant	1,688.3	33,765.7	14.6%	4,922.0	28,843.7	4,429.8
paper mills	638.9	12,778.4	61.7%	7,880.0	4,898.4	-
brick making	291.5	5,830.1	20.0%	1,166.0	4,664.1	-
charcoal[2]	217.4	2,149.5	17.5%	376.2	1,773.3	270.7
rural homes	147.7	2,953.2	12.4%	365.2	2,588.0	-
eateries	42.6	852.5	12.4%	105.4	747.0	-
match factories	24.5	489.1	61.7%	301.6	187.5	-
oil mills	14.2	283.7	61.7%	174.9	108.7	-
wood traders[3]	682.5	13,650.3	25.9%	3,531.7	10,118.6	3,531.7
TOTAL	**3,996.4**	**72,752.6**		**18,823.1**	**56,128.8**	**8,232.2**
Percent of Primary Energy %				**25.9%**	**77.2%**	
Percent of Useful Energy %						**43.7%**

Note:

1. Combustion efficiencies are documented in Appendix 1.4.

[25] Based on survey data, all transport is road transport by truck.

2. Charcoal waste energy includes waste energy from conversion (49.4% efficiency) and waste energy from combustion (17.5% efficiency).

To avoid double counting, the wood trader Prosopis flows is the amount of Prosopis imported or cut by the traders not sold to local users (ie. the amount of wood exported by large traders. Useful energy for the traders assumes a conversion rate equal to that of the Sattur Prosopis energy system (ie. 25.8%).

Further, we estimate approximately 8.2 PJ of useful energy are exported from Sattur (43.7%). We assume 90% of the electricity from the ETA power plant is exported to the Tamil Nadu grid (ie. the amount of electricity not internally consumed). While some of this is likely to be redistributed within Sattur, for simplicity, we assume a 100% export rate for modeling purposes. In addition, based on survey data, 72% of charcoal produced within Sattur is exported out of the taluk. Lastly, we assume the portion of wood exported from the taluk by the wood traders is ultimately converted to useful energy at the same conversion rate as that estimated for the Sattur Prosopis energy economy, 25.9%.

Table 1.17: Prosopis System Energy Exports, 20-year Lifespan

Industry	Useful Energy	Useful Energy Exports	Useful Energy Export %	Note
	TJ/20-yrs	TJ/20-yrs	%	
	[1]	[2]	[3]	[4]
power plant	4,922.0	4,429.8	90.0%	Assumes 90% electricity exported to grid
paper mills	7,880.0	-	-	
brick making	1,166.0	-	-	
charcoal	376.2	270.7	72.0%	Based on survey data
rural homes	365.2	-	-	
eateries	105.4	-	-	
match factories	301.6	-	-	
oil mills	174.9	-	-	
wood traders	3,531.7	3,531.7	100.0%	Assumes wood exported by traders is converted at same efficiency at Sattur Prosopis economy, 25.9%
TOTAL	**18,823.1**	**8,232.2**	**43.7%**	

Lastly, we estimate the EROI of the Prosopis system to be nearly 103 meaning each unit of energy input yields 103 units of energy output.

Table 1.18: EROI of Prosopis System, 20-year Lifespan

Inputs	Outputs	By-Products	EROI
TJ/ 20-yrs	TJ/ 20-yrs	TJ/ 20-yrs	
[1]	[2]	[3]	[4]=([2]+[3])/[1]
706.6	72,752.6	-	103.0

Comparison

This section compares the results of the Jatropha and Prosopis models.

Material Intensity

The material intensity of the Prosopis system is substantially less than the Jatropha system. The Prosopis system yields over four times more material outputs than the Jatropha system (Table 1.19, column 2). Further, each unit of input produces between 0.003 to 29.8 units of output in the Jatropha system while the Prosopis system yields over 806 units of output per unit input (Table 1.19, column 5).

Table 1.19: Material Intensity of Jatropha and Prosopis Systems

System	Inputs	Outputs	By-Products & DE	Output: Input
	ktonnes/20-yrs	ktonnes/20-yrs	ktonnes/20-yrs	ratio
	[1]	[2]	[3]	[5]=([2]-[4])/[1]
Prosopis	5.0	3,963.6	51.3	806.982
Jatropha S0	32.4	965.3	-	29.799
Jatropha S1	333,501.4	965.3	-	0.003
Jatropha S2	333,501.4	965.3	273.5	0.004
Jatropha S3	333,501.4	965.3	592.9	0.005
Jatropha S4	333,501.4	965.3	866.3	0.005

Energy Provision

Over the 20-year project lifespan, the Prosopis energy system provides approximately 18.8 PJ of primary energy. This is 3.6 to 15.2 times the useful energy delivered by the Jatropha system, depending on how, if at all, by-products are used within the Jatropha system (column 6, Table 1.20). Although the Prosopis system provides more useful energy, the Prosopis energy system may be less efficient than the Jatropha system at converting primary energy into useful energy, depending on how Jatropha by-products are used. The conversion efficiency of the Prosopis system is approximately 25.9% while the Jatropha system ranges from 26.8% to 41.7% (column 4, Table 1.20).

Table 1.20: Energy Efficiency of Prosopis and Jatropha Systems

System	Primary Energy	Useful Energy	Waste Energy	Useful Energy Percentage	Waste Energy Percentage	Prosopis: Jatropha Useful Energy Ratio
	TJ/20-yrs	TJ/20-yrs	TJ/20-yrs	%	%	ratio
	[1]	[2]	[3]=[1]-[2]	[4]=[2]/[1]	[5]=[3]/[1]	[6]=Prosopis: Jatropha scenario [2]
Prosopis	72,752.6	18,823.1	56,128.8	25.9%	77.2%	
Jatropha S0	4,414.3	1,236.0	3,178.3	28.0%	72.0%	15.2
Jatropha S1	4,414.3	1,236.0	3,178.3	28.0%	72.0%	15.2
Jatropha S2	9,586.4	2,565.2	7,021.2	26.8%	73.2%	7.3
Jatropha S3	9,430.4	3,929.6	5,500.7	41.7%	58.3%	4.8
Jatropha S4	14,602.5	5,258.9	9,343.6	36.0%	64.0%	3.6

Energy Exports

In addition to yielding a higher quantity of useful energy, the Prosopis system provides a larger quantity of this energy to the local Sattur economy (approximately 10.6 million GJ over 20 years, difference of Prosopis useful energy and exports in Table 1.21). Approximately 51% of useful energy in the Prosopis system is exported from Sattur but as described above (Table 1.16), this may be an overestimate as it assumes 100% of electricity generated at the ETA power plant is exported from the taluk. Depending on by-product usage, approximately 53-100% of useful energy in the Jatropha system is exported from the taluk.

Table 1.21: Energy Exports from Jatropha and Prosopis Systems

System	Useful Energy	Useful Energy Exports	Export Percentage
	TJ/20-yrs	TJ/20-yrs	%
	[1]	[2]	[3]=[2]/[1]
Prosopis	18,823.1	8,232	43.7%
Jatropha S0	1,236.0	1,236.0	100.0%
Jatropha S1	1,236.0	1,236.0	100.0%
Jatropha S2	2,565.2	1,814.2	70.7%
Jatropha S3	3,929.6	1,236.0	31.5%
Jatropha S4	5,258.9	3,050.2	58.0%

EROI

Further, the EROI of the Prosopis system is approximately 10 to 90 times greater that of the Jatropha system (Table 1.22, column 6). Each unit of energy input yields over 101 units of energy output in the Prosopis system. The Jatropha system yields between 1 and 10.4 units of energy output, depending on by-product usage and cultivation inputs. Additional research could explore how this metric would change when accounting for the energy requirements of labor in the Prosopis and Jatropha systems.

Table 1.22: EROI of Prosopis and Jatropha Systems

System	Inputs	Outputs	By-Products	Domestic Extraction	EROI	Prosopis: Jatropha ratio
	TJ/20-yrs	TJ/20-yrs	TJ/20-yrs	TJ/20-yrs	ratio	ratio
	[1]	[2]	[3]	[4]	[5]=([2]-[4])/[1]	[6]
Prosopis	706.6	72,752.6	-		103.0	
Jatropha S0	424.5	4,414.3	-	-	10.4	9.9
Jatropha S1	3,850.5	4,414.3	-	-	1.1	89.8
Jatropha S2	3,850.5	4,414.3	-	5,171.1	2.5	41.4
Jatropha S3	3,850.5	4,414.3	5,016.1	-	2.4	42.0
Jatropha S4	3,850.5	4,414.3	5,016.1	5,171.1	3.8	27.2

Land Use Intensity

The Prosopis system is also more favorable in terms of land use intensity than the Jatropha system. A one-hectare stand of Prosopis managed on a three-year coppice rotation yields approximately 16.5 tonnes of Prosopis wood. Assuming sustainable harvesting practices, one third of the area will be coppiced annually, providing 5.5 tonnes per year. A one-hectare plantation of Jatropha, following current recommended spacing patterns, yields just 0.4 tonnes of biodiesel. Thus, the Jatropha system would require nearly 14 times more land to provide an equivalent mass of product as the Prosopis system (Table 1.23, column 3). On an energy basis, the Prosopis system annual yield provides about six times the useful energy per hectare as the Jatropha system.

Table 1.23: Land Use Intensity of Jatropha and Prosopis Systems

	Material		**Energy**	
	Output	**Difference in Land Use Intensity**	**Useful Energy Output**	**Difference in Useful Energy Output**
	tonnes/ha/yr	ratio (P:J)	GJ/ha/yr	ratio (P:J)
Prosopis	5.5		26.9	
Jatropha Biodiesel	0.4	13.9	4.4	6.1

Energy Security

The Jatropha energy system produces liquid transportation fuel that could not service the needs of existing Prosopis users who presently combust Prosopis for heat. While crude Jatropha oil could theoretically be used for some of this demand (Gmuender, Zah et al. 2009), it is unclear what portion, if any, would remain in Sattur taluk as the Government of India has guaranteed the purchase of all biodiesel through its biofuel policies (Government of India 2005). Thus, market forces would likely determine what portion of Jatropha could substitute for Prosopis, if a Jatropha economy is ever firmly established within India.

We surveyed current Prosopis users on how they would respond to supply disruptions. When asked how they would react to a severe Prosopis shortage or a substantial price increase, most industrial users initially dismissed the question and replied there would always be substantial supplies of Prosopis. When pressed, users claimed they would substitute towards other tree species such as Neem, Tamarind, native Prosopis (*Prosopis cineraria*), agricultural wastes such as corncobs and rice paddy waste or LPG. However, the availability and calorific value of other tree species and agricultural wastes is unclear and may cause disruptions in markets that currently use these products such as livestock rearing. Substituting towards LPG presents its own energy security challenges as India currently imports 70% of its fossil fuel needs and is projected to remain so in the future (Energy Information Administration 2011). The user responses are detailed below and summarized in Table 1.24.

The power plant manager replied their stock of Prosopis would be sufficient. However, ETA keeps only a 50-day supply of Prosopis (15,000 tonnes). The paper companies indicated they would use agricultural wastes and charcoal. However, charcoal markets would similarly be affected and the supply of charcoal is unclear. Further, the availability of agricultural wastes is uncertain. Brick makers reported a range of responses from closing down operations, to using other trees such as Tamarind, Neem, Palm or native Prosopis trees. Yet many of these trees have cultural significance, which could also be impacted by a reduction in Prosopis availability. Charcoal makers all reported having to go out of business in the face of a Prosopis shortage as Prosopis is the most widely available and most suitable feedstock for charcoal production. The majority of eateries claimed there is no substitute for Prosopis while the remaining establishments claimed they would substitute LPG, agricultural wastes or other tree species. Three out of six match makers surveyed indicated there is no substitute for Prosopis while the other three manufacturers stated they would use agricultural wastes, paper wastes or other trees. One of the two oil mills surveyed already stopped using Prosopis in favor of rice paddy wastes because of the current price of Prosopis. The second oil mill surveyed indicated there is no substitute for Prosopis.

We did not directly ask rural homes what they would do in light of a Prosopis shortage. However, we did survey households about their current portfolio of fuel uses. Households are currently using a mix of kerosene and LPG in addition to fuelwood. Of the 114 households surveyed, 76% (n=84) are currently using kerosene and 28% (n=32) are currently using LPG. On average, households use approximately 3.2 liters of kerosene a month and about 0.88 cylinders of LPG per month. The government current subsidizes both fuels. The government provides 3 liters per month of kerosene subsidized at Rs. 12 per liter and has also implemented various schemes to encourage LPG adoption. Thus, we anticipate villagers would substitute towards kerosene and LPG if faced with a fuelwood shortage.

Table 1.24: Prosopis Substitute Summary

Users	No Substitute	Other Trees	Agricultural Wastes	Paper Wastes	Charcoal	LPG	Close Business	TOTAL
	#	#	#	#	#	#	#	#
power plant	1							1
paper mills		2	1		1			4
brick making	2	2					1	5
charcoal							4	4
eateries	6	1	1			3		11
match factories	3	1	1	1				6
oil mills	1							1
TOTAL	**13**	**6**	**3**	**1**	**1**	**3**	**5**	**32**
TOTAL %	**40.6%**	**18.8%**	**9.4%**	**3.1%**	**3.1%**	**9.4%**	**15.6%**	**100.0%**

Conclusion

Our study challenges widely held notions that locating biofuels on marginal lands would offer sizeable advantages over production on arable lands. Instead of being 'empty' lands, we find the wastelands targeted for biofuel production in India are significant sources of energy provision for rural communities and industry. In our study site, the Prosopis energy economy located on Sattur's wastelands currently provides 3.6 to 15.2 times more useful energy than would Jatropha biofuels (Table 1.20) and has an EROI of 103, compared to 1.1-10.4 for Jatropha (Table 1.22). Further, the Prosopis economy is substantially less resource intensive than Jatropha as only transportation energy is needed to circulate the wood (Table 1.19).

Lastly, replacing Prosopis with Jatropha is likely to complicate, rather than improve energy security as over 56% of industrial Prosopis users, including the main consumer, the ETA power plant, indicated there are no substitutes for Prosopis available or would have to close down if faced with a Prosopis shortage (Table 1.24). Other users would attempt to use other trees or agricultural wastes whose availability are uncertain. Charcoal makers and some brick makers would likely close their operations in Sattur and perhaps move to other locations as Prosopis is the most suitable and widely available feedstock for their businesses. Household fuelwood users would likely accelerate their transition towards kerosene and LPG, which may place further restraints on the Indian economy as the country is already a net importer of these products.

Appendix 1.1: Summary of Prosopis Surveys by User Group and Location

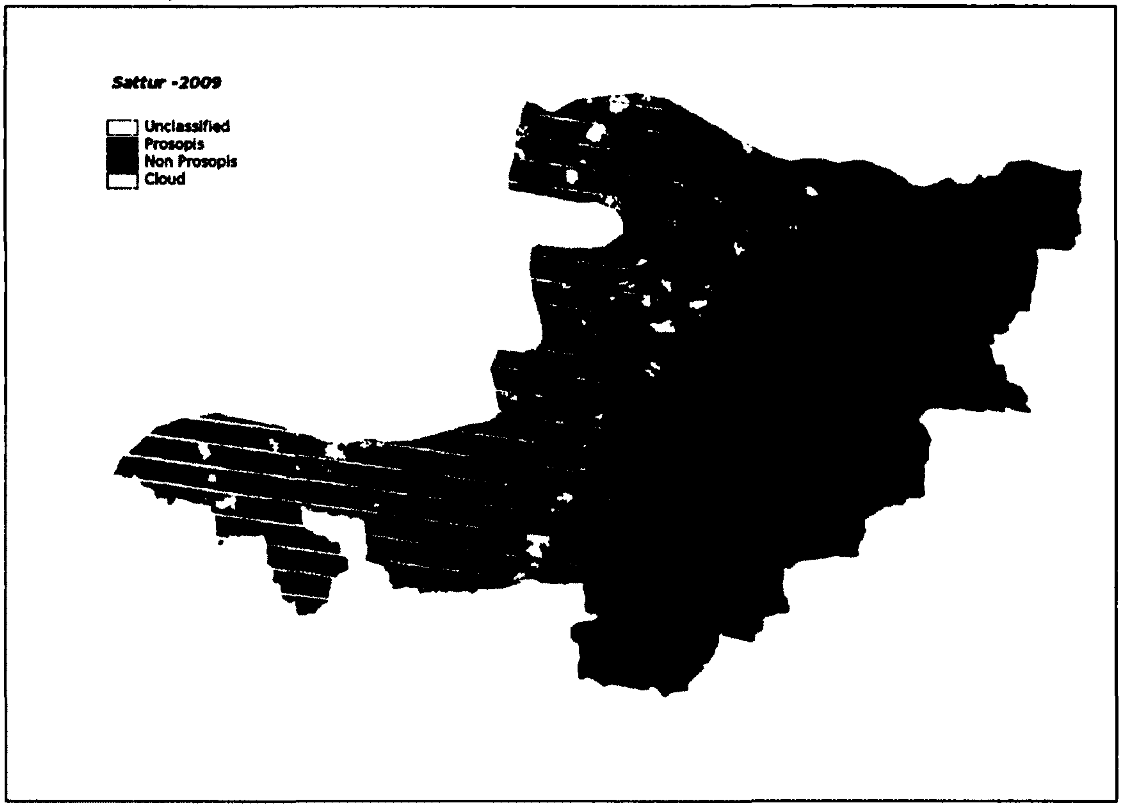
			Prosopis User Surveys									
Village Name	**Fig. 2**	**HHs**	**F**	**Po**	**C**	**B**	**M**	**E**	**Pa**	**O**	**T**	**TOTAL**
	#	#	#	#	#	#	#	#	#	#	#	#
Kumaralingapuram	1	321	2									2
Sandaivur	2	340	2									2
Golvarpatti	3	674	3									3
Nallamanayakkanpatti	4	127	1									1
Pappakudi	5	588	3									3
Ammapatti	6	689	4									4
Attipatti	7	49	1					1				2
Padantal	8	3,810	17				1	3			5	26
Allampatti	9	113	1									1
Kattalampatti	10	439	2									2
Melmadai/ Irrukungudi	11	1,405	4					1				5
Chattrapatti	12	1,497	7		1						2	10
N. Mettupatti	13	513	3									3
Muthulingapuram	14	448	2									2
O. Mettupatti	15	1,205	6				1					7
Surankudi	16	1,272	7				1					8
Nenmeni	17	557	3									3
Ottaiyal	18	417	2				1					3
Mudittalainagalapuram	19	250	2		1							3

Chinnodaippatti	20	452	2									2
Sevalpatti	21	1,080	5			4		3	1	1	1	15
Kangarakottai/ Keelachalaiahpuram	22	1,327	5				2					7
Chinna Tambiyapuram	23	101	1						2			3
Tulukkankurichchi	24	487	3									3
Sinduvampatti	25	189	1			1						2
Sanankulam/ Sivasankapatti	26	151	1				1					2
Sankarapandiyapuram	27	723	4									4
Ayyampatti	28	150	1		1							2
Kukanaparai	29	336	1								2	3
Subramaniapuram	30	45	1									1
Muliseval	31	386	2							1		3
Servaikkaranpatti	32	80	2									2
Uppathur	34	495	0									0
Uthupatti	35	286	4									4
Sippipparai	36	628	3									3
Nallamuttanpatti	37	106	1		1							2
Peranyyanpatti	38	326	2	1				1				4
Kanjampatti	39	468	3								1	4
Sattur town	dark block							2				2
TOTAL	**37**	**22,209**	**114**	**1**	**4**	**5**	**7**	**11**	**3**	**2**	**11**	**158**

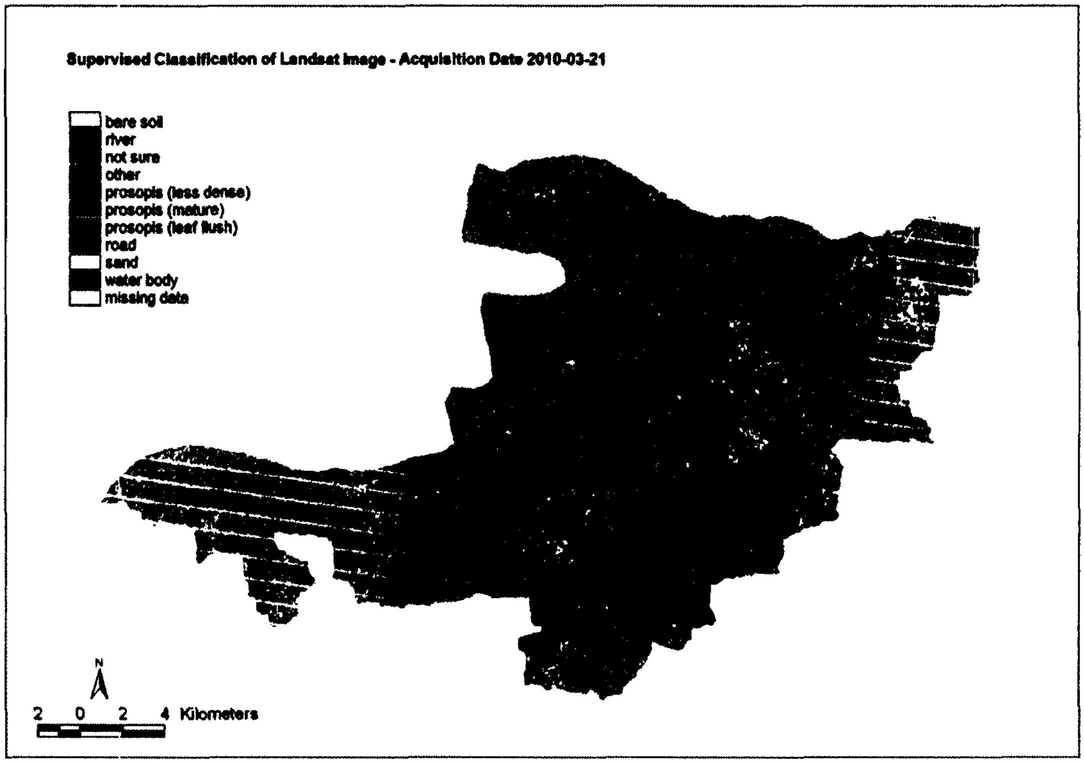
Key: HH=households, F=fuelwood, Po=power plant, C=charcoal, B=bricks, M=match, E=eateries, Pa=paper mills, O=oil mills, T=wood traders.
Note: No surveys were conducted in Ovvanayakkanpatti (#33, Fig. 2) because the village no longer existed at the time of our fieldwork.

Appendix 1.2: Prosopis Area Classification

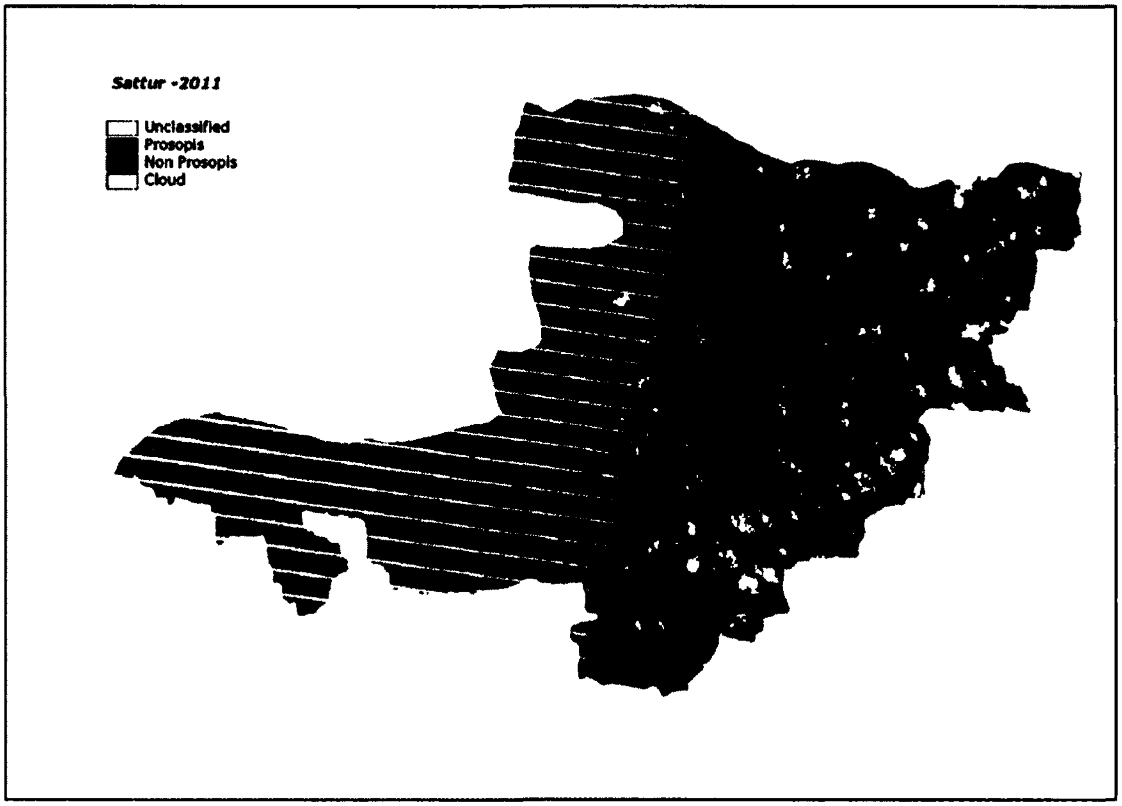
November 29, 2009



March 21, 2010



January 19, 2011



Appendix 1.3: Jatropha Modeling Assumptions

Stage	Parameter	Value	Unit	Source
Nursery	nursery saplings	2,083.33	saplings/ha	calculated based on tree spacing requirements
Nursery	nursery sapling survival rate	0.80	%	(Whitaker and Heath 2008)
Nursery	nursery area	465.96	ha	calculated from sapling requirements
Nursery	seedling gestation	3.00	months	Emami survey
Nursery	nursery irrigation system	0.55	KWh/ha	Emami survey
Cultivation	Prosopis area	16,573.10	ha	remote sensing analysis (Appendix 1.2)
Cultivation	tree spacing	4x1.5	m^2	Emami survey
Cultivation	irrigation system electric capacity	7.50	kW for 2/5 hrs/wk for 10 acres	Emami survey
Cultivation	irrigation duration	52.00	weeks/yr for 3 years	Emami survey
Cultivation	water Requirements	15*10^6	L/ha	(Trabucco, Achten et al. 2010)
Cultivation	weeding duration	2.00	times per year for first 5 years	(Whitaker and Heath 2008)
Harvest	seed yield	1.50	kg/tree	(Francis, Edinger et al. 2005)
Harvest	gestation period	4.00	years	(Brittain and Lutaladi 2010)
Oil Extraction	Jatropha seed oil content	0.35	%	(Whitaker and Heath 2008)

Oil Extraction	oil extraction efficiency	0.22	%	average of literature values: (Reinhardt, Gaertner et al. 2007; Gmuender, Zah et al. 2009; Sharma and Singh 2009; Brittain and Lutaladi 2010)
Oil Extraction	seed crusher capacity	500.00	kg/hr	ACS survey
Oil Extraction	seed crusher electricity usage	76.00	kW	ACS survey
Oil Extraction	biogas yield	0.39	m^3/kg seedcake	(Almeida, Achten et al. 2011)
Oil Extraction	biogas calorific value	21.60	kWh/m^3	(Almeida, Achten et al. 2011)
Transesterification	transesterification efficiency	0.97	%	(Whitaker and Heath 2008)
Transesterification	unit electricity requirements	36.00	kWh/1000 kg biodiesel	(Government of India 2003)
Transesterification	Jatropha biodiesel calorific value	39.65	MJ/kg	(Achten, Verchot et al. 2008)
Transport, general	diesel fuel efficiency 3.5-7.5 tonne truck	Redacted	g/vkm	EcoInvent
Transport, general	diesel fuel efficiency 7.5-16 tonne truck	Redacted	g/vkm	EcoInvent
Transport, general	diesel fuel efficiency 16-32 tonne truck	Redacted	g/vkm	EcoInvent
Transport, general	Diesel fuel calorific value	44.83	MJ/kg	(NIST, 2001)

Appendix 1.4: Prosopis Modeling Assumptions

Parameter	Value	Unit	Source
Prosopis wood calorific value	18.9	MJ/kg	lab analysis
Prosopis charcoal calorific value	31.1	MJ/kg	lab analysis
Diesel fuel calorific value	44.8	MJ/kg	(National Institute of Standards and Technology 2001)
Prosopis area	16,573.1	ha	remote sensing analysis
Prosopis biomass stock	16.5	tonnes/ha	(Bailis and McCarthy 2011)
Prosopis wood import collection radius	14.9	km	estimated based on survey import distances
Prosopis wood internal transport distance	12.4	km	estimated by randomly assigning 85 collection points
Prosopis wood export distance	170.7	km	estimated based on survey export distances
Prosopis charcoal export distance	1,032.0	km	estimated based on survey export distances
power plant efficiency	0.1	%	survey data
paper mills efficiency	0.6	%	survey data and boiler efficiency literature review: (Council of Industrial Boiler Owners 2003)
brick making efficiency	0.2	%	survey data and literature review: (Bhattacharya, Attalage et al. 1999)
charcoal conversion efficiency	0.5	%	survey data
charcoal combustion efficiency	0.2	%	(Smith, Uma et al. 2000)

rural homes efficiency	0.1	%	survey data and literature review: (Gupta and Ravindranath 1997; Pohekar and Ramachandran 2004; Rajvanshi 2004)
eateries efficiency	0.1	%	survey data and literature review: (Gupta and Ravindranath 1997; Pohekar and Ramachandran 2004; Rajvanshi 2004)
match factories efficiency	0.6	%	survey data and boiler efficiency literature review: (Council of Industrial Boiler Owners 2003)
oil mills efficiency	0.6	%	survey data and boiler efficiency literature review: (Council of Industrial Boiler Owners 2003)

Appendix 1.5: Jatropha MFA Results by Material, 20-year Lifespan

Stage	Material	Material Type	TOTAL	Total MFA Percentage	Note
			ktonnes/20-yrs	%	
	[1]	[2]	[2]	[3]	[4]
Nursery	Seeds	input	0.0	0.0%	
	NPK Fertilizer	input	0.1	0.0%	
	Pesticide	input	0.0	0.0%	
	Fungicide	input	0.0	0.0%	
	Water	input	29.1	0.0%	
	Saplings	output	34.5	0.0%	
	Seed transport	input	0.0	0.0%	Diesel fuel for seed, fertilizer, pesticide and gypsum transport
	TOTAL		**63.7**	**0.0%**	
Land Prep	Gypsum	input	4.1	0.0%	
	Prosopis uprootings	DE	273.5	0.1%	DE is direct extraction

	Diesel	input	0.5	0.0%	Diesel usage for land clearance and Prosopis uprooting
	TOTAL		**278.1**	**0.1%**	
Cultivation	NPK Fertilizer	input	121.4	0.0%	
	Pesticide	input	0.3	0.0%	
	Water	input	333,318.1	99.3%	
	TOTAL		**333,439.8**	**99.3%**	
Harvest	Jatropha Seeds	output	704.4	0.2%	
	Jatropha Husks	waste	422.6	0.1%	
	Seed transport	input	0.1	0.0%	Diesel for transporting seeds to oil extraction unit
	TOTAL		**1,127.0**	**0.3%**	
Oil Extraction	Jatropha Oil	output	115.0	0.0%	
	Jatropha Seedcake	by-product	589.4	0.2%	
	Water	input	17.6	0.0%	
	TOTAL		**722.0**	**0.2%**	

Transesterification	Alcohol	input	6.0	0.0%	
	KoH Catalyst	input	1.0	0.0%	
	Water	input	3.1	0.0%	
	Biodiesel	output	111.5	0.0%	
	Glycerine	by-product	3.4	0.0%	
	TOTAL		**125.1**	**0.0%**	
SYSTEM TOTAL			**335,755.7**	**100.0%**	

Appendix 1.6: Jatropha EFA Results by Material, 20-year Lifespan

Stage	Material/ Activity	Material Type	TOTAL	Total EFA Percentage	Note
			TJ/20-yrs	%	
	[1]	[2]	[3]	[4]	[5]
Nursery	Fertilizer	input	1.9	0.0%	Includes transport energy
	Pesticide	input	0.2	0.0%	Includes transport energy
	Electricity	input	0.0	0.0%	For irrigation
	transport	input	0.0	0.0%	Transport for seeds and fungicide
	TOTAL		**2.1**	**0.0%**	
Land Prep	Prosopis uprootings	DE	5,171.1	28.0%	DE is domestic extraction; figure represents primary energy of Prosopis uprootings
	land clearance	input	22.0	0.1%	Diesel for land clearance
	transport	input	0.1	0.0%	Transport for gypsum

	TOTAL		**5,193.3**	**28.1%**	
Cultivation	Fertilizer	input	3,264.0	17.7%	Includes transport energy
	Pesticide	input	57.4	0.3%	Includes transport energy
	Electricity	input	43.1	0.2%	For irrigation
	Weeding	input	59.4	0.3%	Diesel for weeding
	TOTAL		**3,423.9**	**18.6%**	
Harvest	transport	input	2.5	0.0%	Transport for seeds
	TOTAL		**2.5**	**0.0%**	
Oil Extraction	Seedcake biogas	by-product	5,016.1	27.2%	
	Electricity	input	385.4	2.1%	
	TOTAL		**5,401.5**	**29.3%**	
Transesterification	Electricity	input	14.5	0.1%	
	Biodiesel	output	4,414.3	23.9%	Figure is primary energy of biodiesel; Includes transport energy
	TOTAL		**4,428.7**	**24.0%**	

Chapter 2. What Wastelands? Evaluating the Gap between Wasteland Policy and Practice in India

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Abstract

In an effort to boost energy security, mitigate global warming and alleviate rural poverty, in 2003, the Government of India initiated a program to cultivate *Jatropha curcas* (hereafter Jatropha) on 17.4 million hectares (mha) of wastelands, a government classification of marginal lands. Despite these ambitious efforts, various experts in and outside India are considering the initiative a failure due to insufficient research and development for seed and production technology and inadequate financial and institutional support. By reducing the issue to one of technology or financing, such assertions have given way to "Jatropha 2.0", the recent revival interest in Jatropha centered around improved seed varieties such as SG Biofuels' Jmax™ hybrid.

But what if the failure is more a question of land assessment than technology? There has been little research done to critically examine the concept of wastelands or to evaluate whether Jatropha is suitable for such spaces. In this paper, I evaluate the politics of wasteland classification in India and reveal how these lands are socially constructed spaces with an extensive policy history of failed development initiatives since the end of Colonial rule. Further, I find a similar "policy recipe" underlying both previous wasteland

development programs and the present day biodiesel program. I examine the causes of failures for past schemes through a literature review and draw parallels to today's biodiesel program through a field study with key stakeholders involved with Jatropha promotion in the state of Tamil Nadu, India.

I posit two main hypotheses for failures that have been historically under-examined in the literature. First, wasteland assessments inadequately capture the multiple dimensions of these territories. Wastelands are simultaneously biophysical, economic, social and political spaces and current land assessments focus mainly on the biophysical and economic dimensions. Second, stakeholder perceptions of wasteland differ greatly from the representation of wastelands in policy documents. Stakeholders are united in the belief that there is no such thing as wastelands but with different corollaries. Government and corporate stakeholders asserted there were no such thing as wastelands, only wasted land while village stakeholders claimed there was no wasteland in villages as all lands currently serve important functions. NGO perceptions are currently more in line with village perceptions yet their perceptions have shifted over time. These perceptions stand is stark contrast to policy documents and wasteland assessments, which assert large swaths of the country of lying in waste (historically 17-50% of the total geographic area) and available for development.

By unpacking the concept of wastelands, this paper seeks to improve society's understanding of the prospects and limitations of growing biofuels on marginal lands, currently one of the most prescribed measures to promote sustainable biofuel production.

Introduction

In an effort to alleviate energy security, global warming and rural poverty, in 2003, the Government of India initiated a program to cultivate *Jatropha curcas* (hereafter Jatropha) on 17.4 million hectares (mha) of wastelands, a government classification of marginal lands (Government of India 2003). Despite these ambitious efforts, various experts in and outside India are considering the initiative a failure due to insufficient research and development for seed and production technology and inadequate financial and institutional support (Kant and Wu 2011; Kumar, Chaube et al. 2012). By reducing the issue to one of technology or financing, such assertions have given way to "Jatropha 2.0", the recent revival interest in Jatropha centered around improved seed varieties such as SG Biofuels' Jmax™ hybrid (Lane 2011).[26]

But what if the failure is more a question of land assessment than technology? There has been little research done to critically examine the concept of wastelands or to evaluate whether Jatropha is suitable for such spaces. In this paper, I evaluate the politics of wasteland classification in India and reveal how these lands are socially constructed spaces with an extensive policy history of failed development initiatives since the end of Colonial rule. Further, I find a similar "policy recipe" underlying both previous wasteland development programs and the present day biodiesel program. I examine the causes of failures for past schemes through a literature review and draw parallels to today's

[26] SG Biofuels recently received $17 million in Series B financing for its hybrid technology and associated Jatropha projects (http://www.sgfuel.com/AdminSavR/en/news/news_item.php?news_id=85).

biodiesel program through a field study with key stakeholders involved with Jatropha promotion in the state of Tamil Nadu, India.

I posit two main hypotheses for failures that have been historically under-examined in the literature. First, wasteland assessments inadequately capture the multiple dimensions of these territories. Wastelands are simultaneously biophysical, economic, social and political spaces and current land assessments focus mainly on the biophysical and economic dimensions. Second, stakeholder perceptions of wasteland differ greatly from the representation of wastelands in policy documents. Stakeholders are united in the belief that there is no such thing as wastelands but with different corollaries. Government and corporate stakeholders asserted there were no such thing as wastelands, only wasted land while village stakeholders claimed there was no wasteland in villages as all lands currently serve important functions. NGO perceptions are currently more in line with village perceptions yet their perceptions have shifted over time. These perceptions stand is stark contrast to policy documents and wasteland assessments, which assert large swaths of the country of lying in waste (historically 17-50% of the total geographic area) and available for development.

By unpacking the concept of wastelands, this paper seeks to improve society's understanding of the prospects and limitations of growing biofuels on marginal lands, currently one of the most prescribed measures to promote sustainable biofuel production.

The article proceeds as follows. First, I present a literature review of political ecology research related to the differences between policy and practice, the main body of literature to which this article hopes to contribute. After an analysis of wasteland development discourse, discussion remarks are offered to conclude the paper.

Literature Review

Critically analyzing "dominant narratives" of conservation and development policy, such as the causes and consequences of land degradation, is a foundational pillar of political ecology (Robbins 2004). Such analyses have repeatedly revealed disconnects between policy prescriptions and practice, a phenomenon Mosse (2004) refers to as "the black box of unknowing". As Mosse futher reveals, a political ecology approach focuses on opening up the black box to better understand how policy outcomes are produced. Such an analysis will help untangle the political factors shaping policy, which often help to explain why policies, at least on paper, appear to be coherent representations while often differing markedly from realities on the ground. These factors and the related power dynamics of policy formulation also help to explain why similar policies are often recycled, despite repeated failures to meet stated policy objectives.

Analyzing discourse of policy helps to unveil the political and power dynamics shaping policy. Such analyses have critically examined various oft-repeated causes and prescribed solutions to development problems and have often concluded the premises upon which programs were designed were invalid. Yet the solutions are often recycled in future programs because of power imbalances between policymakers and intended program beneficiaries. Dove's (1993) work examining the discursive underpinnings of policies incorrectly linking tropical forest deforestation to indigenous community forest use is a particularly salient example.

As theorized by Foucault, discourse "governs the way that a topic can be meaningfully talked about and reasoned about" (Hall 2001: 72). Discourse is a complex practice built on dispersed networks of power relations that help circulate select viewpoints (Foucault 1972; Foucault 1980). The knowledge circulated through discourse often appears as self-evident truths with historic consistency, a façade Foucault aims to challenge through a critique of discursive formations.

A discursive formation exists whenever consistent patterns among a number of dispersed statements, objects, themes, or concepts can be identified. Foucault does not recommend an outright rejection of discursive formations but rather advocates "tear(ing) away from them their virtual self-evidence and … to recognize that they are not the tranquil locus on the basis of which other questions … may be posed" (Foucault 1972: 28-29). This entails examining how discursive formations are constructed, the rules by which they are formed and maintained, and what alternative views they may obscure (Foucault 1972). Doing so will unveil the power structures through which discursive formations are established and circulated.

Further, discourses are constraining as they structure how topics are to be discussed, analyzed, and questioned. These limits are not static and are subject to continual negotiation and possible contestation (Barnes and Duncan 1992). As result, discourses rarely reflect unity across stakeholders and are as powerful for what they include as well as exclude. Discursive analysis, therefore, can reveal the fractures amongst stakeholders and show the "other unities" made invisible by the prevailing discourse (Foucault 1972).

Typically, discourses appear as apolitical representations of consensus. This occurs because dominant stakeholder groups, most often political elites, control their formulation. This language serves to "structure perceptions of status, authority, merit, deviance, and the causes of social problems" (Edelman 1974: 296). By establishing norms, discourse also divides objects into "acceptable" and "unacceptable" categories with those in the latter becoming subjects for "improvement" schemes (Foucault 1979). It thus becomes imperative to examine the underlying political-economic factors supporting such divisions.

A discursive analysis of the term "wasteland" reveals contentious political underpinnings. In his examination of colonial wasteland development policy in India, Gidwani (1992) characterizes the term as a phrase ambiguously defined but universally accepted as "bad". Constructed as the opposite of "value", policies were thus designed to eliminate wastelands. The term itself dates back to Locke (2011 (1680)), who coined the term to refer to all lands not privately held. Privatizing wastelands, Locke posited, would not only reduce the amount of nature lying in waste but would also improve overall social welfare "for the provisions serving to the support of human life, produced by one acre of inclosed and cultivated land, are . . .ten times more than those which are yielded by an acre of land of an equal richness lying waste in common" (Locke 2011 (1680): sect. 37).

Gidwani also credits Locke with adding a moral dimension to the term wasteland through his conception of property as a natural right bestowed by god (Gidwani 1992). To waste land (by not improving its productive capacity) was thus immoral. Whitehead (2010) extends this analysis to reveal how the term was also used in India's colonial forest policies to divide land users. Tribal communities, the typical users of forests, were deemed savage while private land owners (primarily caste members) were considered civilized. Collectively, these interpretations reveal the disciplinary motives of wasteland development policy, which was to turn "waste" into "value" and "savage" into "civilized".

This prevailing discourse of wasteland, which Gidwani (1992) aptly refers to as the "waste", "value" and "property" triad, obscured the political dimensions of colonial wasteland assessment and customary uses of such lands. Gidwani asserts the category was "indiscriminately applied" (Gidwani 1992: PE-43) because while some scholars on the colonial settlement claimed the extent of wastelands "was absolutely unknown in any district" (Gidwani 1992: PE-39, citing Hunter, 1894), a wasteland category was part of all land classification systems. Further, while Governor General Cornwallis asserted one-third of India was lying in waste, the colonial historian WW Hunter acknowledged some of the areas classified as waste were used as village common lands (Gidwani 1992).

The moral connotations and disciplinary techniques of wasteland development outlived the colonial era and persist in similar fashion to this day. Ariza-Montobbio, et al (2010) briefly examine the politics of wasteland development in their political ecology analysis of Jatropha biofuel promotion in India. Ariza-Montobbio, et al rightly assert the concept of wasteland development is hard to argue against because of the negative connotations of "wasteland". Yet this awards the term a degree of political malleability, as it is uncertain what types of land are classified as wastelands. As the state often controls wasteland assessment procedures, this ambiguity imbues the state with a substantial degree of political capital.

Various wasteland development schemes have been implemented between Colonial times and present day biofuel promotion. Saigal traces the history of wasteland development policy and documents five historic shifts (Saigal 2011). Taking Saigal's historic timeline as a foundation, one objective of this paper is to analyze the discourse patterns of wasteland development policy from Colonial times to the present. What emerges is a similar "policy recipe" that has been continuously recycled. At the heart of this recipe is the concept of wasteland, which has largely gone unchallenged due to its discursive power.

The discursive power of policy often masks fractures in stakeholder perceptions, which has been a particular focus for political ecologists. Beginning with the seminal work of Blaikie (1985), political ecologists have recognized perceptions of land degradation can vary significantly across stakeholders. Yet these multiple perspectives are rarely reflected in policies, which, according to Mosse (2004), attempt to present a unified interpretation of events for which a particular set of recommendations appears to be the most logical solution. Further, as was again first posited by Blaikie (1985), policies and their prescriptions are often technically oriented, which can disguise the political and social dimensions underlying the issues. Theoretically motivated by Foucault's (1991) concept of governmentality, influential political ecology research referred to this process of de-politicization as "anti-politics" (Ferguson 1994) and "rendering technical" (Li 2007).

Political ecology attempts to reveal fractures in perceptions, with particular emphasis on class dynamics and power relations. Further, such analyses are often "bottom up" with a focus on the communities that may be most impacted by development and conservation policies. As result, numerous political ecology works have revealed how local knowledge is frequently at odds with dominant policy narratives. Notable examples in the area of land use change include Dove's (1993) work challenging the "Rainforest Crunch" thesis, Fairhead and Leach's (1996) work countering Guinean afforestation policies and Scoones' (1996) work questioning the linkages between livestock grazing and land degradation in Zimbabwe. Failing to incorporate local knowledge, these authors imply, may be a possible reason why development schemes often fail to achieve their stated objectives.

In addition to stakeholder perception fractures related to policies, Robbins' (2001) work reveals similar fractures in perceptions between satellite images and stakeholder characterizations. Instead of clarifying the nature and direction of land use change, Robbins asserts satellite imagery simply reinforces previously held perceptions. In a participatory remote sensing exercise in Rajasthan, India Robbins finds forestry officials interpret the spread of the invasive species *Prosopis juliflora* (hereafter Prosopis) as a sign of successful afforestation while villagers consider it a symbol of land degradation because of the tree's negative impacts on farming activities. Thus, while forestry officials would label Prosopis lands as forest, villagers would either give the lands no name or refer to them as waste. This distinction is relevant to the linkages between wastelands and biofuels in India today as one of the two main sources of wasteland estimates is conducted via remote sensing.

This paper threads together and builds upon the foundational works of Gidwani, Saigal and Ariza-Montobbio, et al. I identify a wasteland development "policy recipe" that consistently appears in policy proposals since the start of Indian independence. While promising ambitious land restoration and rural development benefits, many of these programs have failed to achieve these objectives. I examine the causes of the alleged failures and drawing upon classic political ecology analyses that challenge dominant narratives, posit the failures result from incomplete conceptions of wastelands. Further, through a case study of Jatropha stakeholder perceptions, primarily in Tamil Nadu, India, I reveal fractures in stakeholder perceptions on the existence of wastelands. Yet the discourse of wasteland development continues to resemble that of the Colonial era first highlighted by Gidwani, which is simultaneously testament to the strength of the wasteland narrative and a call for a critical examination, which this paper hopes to provide.

Analysis

Wasteland Development Policy Recipe

As detailed above, the impetus to "develop" wastelands has existed in India since the Colonial Era. However, as documented by Saigal (2011), the objective of such programs has shifted in accordance with the country's larger policy objectives, which have often been linked to the development objectives of the international community. Saigal also briefly touches upon the repeated failure of wasteland policies to meet stated objectives, particularly in regards to rural development. Yet, as policy outcomes are never complete successes and failures, it is imperative to inquire who gained and lost from policy outcomes.

In this section, using the policy shifts documented by Saigal, I critically examine the rationale and outcomes of India's past wasteland development schemes. I then analyze India's current biofuel policy in relation to these findings. While Saigal notes the objectives of wasteland development have sifted over time, I find a striking consistency in policy discourse and rationale. What emerges is a similar "policy recipe" across various wasteland development policies.

I also offer two hypotheses to explain why past wasteland development schemes have failed to achieve their stated objectives. First, past and present wasteland assessments are incomplete, particularly in regards to the livelihood dimensions of wastelands. Second, perceptions of wastelands differ amongst stakeholders, which is at odds with wasteland policy discourse. Regarding India's biofuel policy, I found differences in perceptions across central, state and village levels as well as within the corporate and civil society sectors.[27] At the local level, villagers believe there are no such thing as wastelands because all lands are currently being used. Not accounting for local perceptions in central government policy planning may in part explain why wasteland development programs have failed to take hold.

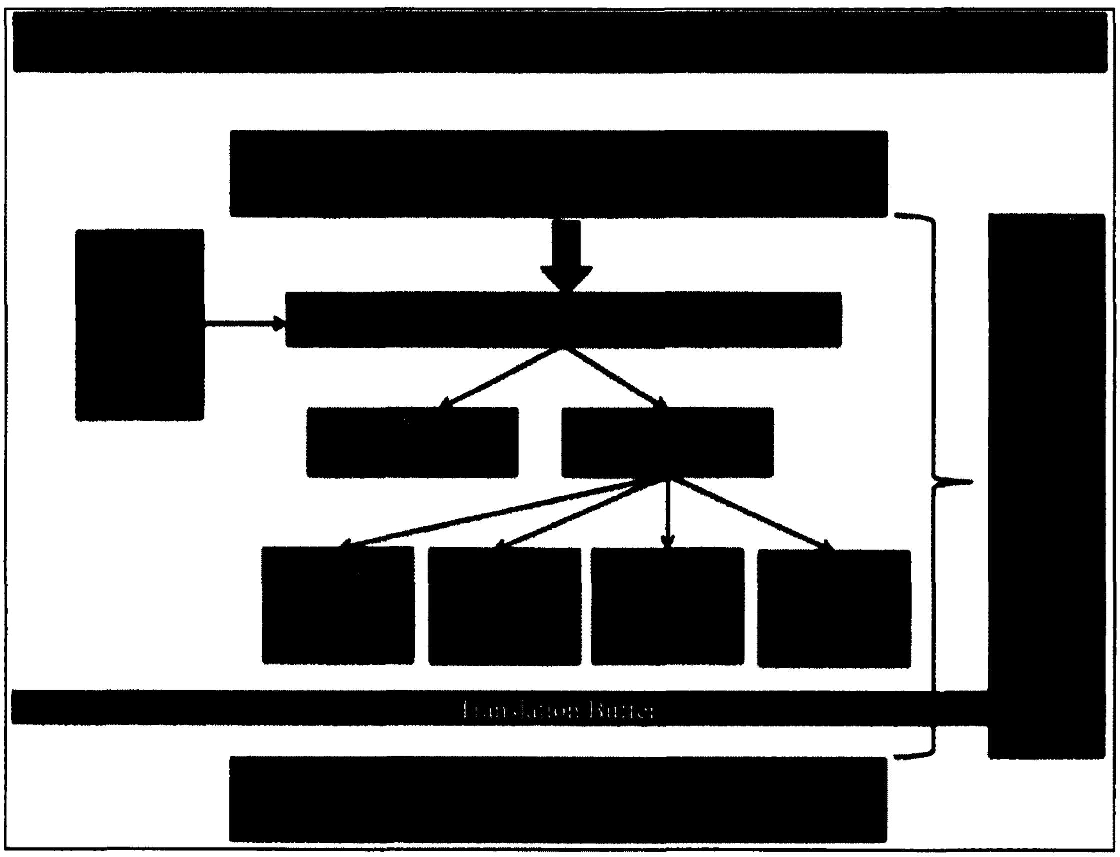
Saigal documents five historic shifts in wasteland development policy since Colonial times: food security (Independence to roughly 1970), social forestry (1970s), rural development (1980s), watershed development (1990s), and climate change (2000s), of which India's biofuel policy is a component. Saigal cogently traces the emergence and evolution of this policy history and briefly touches on policy outcomes.

Synthesizing Saigal and additional resources on each of these policy shifts, I identify striking similarities in the policy components and outcomes across time. The key themes in the "policy recipe" that emerge are: (1) a crisis narrative often linked to similar suppositions at the international level and (2) ambitious government initiatives to address the perceived crisis that include: (a) the establishment of a high-level government commission and in some instances, a government department to evaluate the issue (b) substantial wasteland assessments (c) an ambitious wasteland development target and (d) buzzword-filled policy language (Cornwall and Brock 2005) often centered on the

[27] I did not interview development agencies for this study because India's Jatropha program has largely been a domestic endeavor.

potential rural development benefits of wasteland development. Underlying these policies is a belief that wastelands are underutilized areas that could be put to more productive use, thus staving off the perceived crisis. This "recipe" represents the "black box of unknowing" in the gap between wasteland development policy and practice as represented in Figure 2.1. The translation buffer depicted in the figure represents how fractured stakeholder perceptions of wastelands are filtered and underrepresented in policy language.

Figure 2.1: Wasteland Development Policy Recipe



Crisis Narrative

Each shift in wasteland policy was constructed to respond to a perceived crisis within India. In numerous instances, the crisis within India also corresponded to a larger international development crisis that was currently being addressed by various UN and bi-lateral development agencies. As summarized in Table 2.1, the crises for each policy shift were famines for which the Green Revolution was developed to address (food security) (Griffin 1974), the "other" energy crisis concerning perceived fuelwood shortages throughout the developing world (social forestry) (Eckholm 1975), lack of people's participation in natural resource management, which ushered in the era of Community Based Natural Resource Management (rural development) (Leach, Mearns et al. 1999), soil erosion and land degradation (watershed development) (Farrington, Turton et al. 2000) and lastly, international concerns over global warming and energy security (climate change/biofuels).

In examining the causes of the crises, numerous policies such as social forestry implicated the rural poor in facilitating the crisis (Eckholm 1975), part of a trend in natural resource management Blaikie refers to as the "classic or colonial approach" (Blaikie 1985). Each policy recommended extending agriculture or forestry into wastelands in order to address the crisis and especially in the case of social forestry, to provide the rural poor with alternative resources in order to protect high-value forest resources (Pathak 1994). Yet, local fuelwood users in India and throughout the developing world did not perceive such shortages (Agarwal 1986). Further, tree species selected for social forestry plantations, particularly eucalyptus, were often incommensurate with local needs and more suitable for the emerging pulp and paper industry at the time (Agarwal 1986; Saxena 1994).

Government Initiatives

Government Agencies and Missions

In response to the crises, the Government of India often convened government commissions to examine the issue in depth. This would often lead to a policy "mission"[28] or law and in some instances, the establishment of a government agency to specifically address the issue.

The 1946 Statement of Agriculture and Food Policy in India established goal of "win(ning) freedom from foreign bread and achieving food self-sufficiency" (GOI 1976: 143) and lead to the Integrated Production Programme of 1950 (Saigal 2011). India's network of agricultural universities was also established in this period many of which played a key role in the Green Revolution (Parayil 1992). Social forestry emerged from the 1976 National Commission on Agriculture Report (GOI 1976), which advocated tree planning on wastelands as a means of ensuring fuelwood supplies for rural communities and preserving forest resources.

[28] In India, government Missions are the highest level policy issues.

The evolution of rural development policies in the 1980s marked a hallmark in wasteland development. In this era, the National Remote Sensing Agency (NRSA) was established to estimate the extent of land degradation in the country. The agency's first analysis estimated approximately 1.3 mha of land per year was lost to degradation (Saigal 2011). Additionally, the National Wastelands Development Board (NWDB) was formed to mitigate land degradation and rural poverty (Hegde and Abhyankar 1985). This marked the first formal recognition of the possible links between land degradation and rural poverty. Prime Minister Rajiv Gandhi also provided Mission status to the NWDB underscoring this important policy shift. Civil society also began engaging with wasteland development with the formation of the Society for the Promotion of Wasteland Development (SPWD) in 1984 (Saigal 2011).

In response to the energy crises of the 1970s, the Government of India established the Commission for Additional Sources of Energy (CASE) in 1981, which was the initial predecessor agency to today's Ministry of New and Renewable Energy (MNRE) (MNRE 2012). As stated on the Ministry's website, the historic goal of the agency has been to ensure India's energy security by promoting the use of renewable energy resources (MNRE 2012).

The watershed development era began after the Hanumantha Rao report was issued in 1994 (Government of India 1994). The report recommended addressing land degradation issues on a watershed basis as a way to best promote rural development and conservation. Further, the Dharia Committee Report on 1995 attempted to estimate the extent of wastelands in the country by analyzing historic land use statistics (Government of India 1995).[29]

To address the issue of climate change, the Government of India has initiated numerous commissions of which biofuels is a component. The overarching policy is the National Action Plan on Climate Change (NAPCC), which includes eight Missions (Government of India 2008). The Missions relevant to wasteland development include the National Solar Mission, The National Mission for a Green India and the National Mission for Sustainable Agriculture. All of these Missions seek to establish projects on wastelands to mitigate climate change. The 2009 National Biofuels Policy (Government of India 2009) emerged out of the 2003 Planning Commission report that called for establishing a National Mission on Biodiesel (Government of India 2003). Although not formally part of one of the NAPCC Missions, the biofuel policies are frequently discussed in the context of climate change and energy security.

<u>Wasteland Development Targets and Assessments</u>

Since the Green Revolution, India has advocated a 33% afforestation target by planting trees on wastelands (Saigal 2011). This is also the main goal of the National Mission for a Green India, part of the NAPCC (GOI 2010). Further, Prime Minister Rajiv Gandhi set a wasteland rehabilitation goal of 5 mha per year, which in part led to the creation of the NWDB (Hegde and Abhyankar 1985).

[29] This work was separate from the work of the NRSA. Wastelands are still estimated through both land use statistics and remote sensing. As will be analyzed in the proceeding section, there is little correspondence between these estimates.

The policies have also included estimates of wasteland areas, which have often varied significantly due to differing assessment procedures.[30] Yet all estimates have been sizeable, which has likely helped fuel the ambitious development targets that next result.

As previously discussed, despite limited scientific evidence, Colonial administrators estimated approximately one-third of India's land area was wasteland (Gidwani 1992). The NCA was the first attempt to estimate the extent of wastelands. Its estimate of 175 mha amounted to over 53% of the geographic area of the country. Although criticized within government and civil society (Eswaran 2001), this figure has been widely citied throughout India's wasteland development policy history, most recently in the Dharia Commission Report (Government of India 1995).

In its first report, the NRSA estimated 55.4 mha, approximately 17% of the country (Saigal 2011). Initial estimates from the NWDB and SPWD were 123 mha and 130 mha, respectively (Eswaran 2001). None of these estimates screened for the livelihood significance of wastelands (documented in more detail below) although these services have been qualitatively discussed in numerous forums (Hegde and Abhyankar 1985; Saxena 2001).

[30] Present day wasteland estimation procedures will be further discussed in the proceeding section.

Buzzwords

A final theme that emerges from past wasteland development schemes is the use of buzzwords to mobilize support for the initiatives. According to Cornwall and Brock (2005), such words are used to imbue development policy with a sense of purposefulness and optimism while the terms themselves are often nebulous and emotive. The words are called buzzwords because they reflect the dominant development paradigms of the day. Yet language is never neutral and the use of such words influences how development programs are conceptualized. Drawing back to Foucault's theories on discourse elements, buzzwords help to obscure the politics of development and help frame development policy recommendations as self-evident truths.

Most of the buzzwords critiqued by Cornwall and colleagues carry positive connotations that speak to the potential benefits of development programs.[31] Yet the term wasteland, with its negative connotations, can also be considered a buzzword as it is used to conjure images of inefficiency, degradation and emptiness; hence the products that can be eliminated through development schemes. Prominent buzzwords associated with India's wasteland development schemes are poverty reduction (rural development), community (rural development, watershed development), participation/empowerment (watershed development), energy security (social forestry, biofuels) and environment (rural development, watershed development, biofuels). As the works of Cornwall and Sachs (1992) have revealed, critically assessing the language of development has demonstrated

[31] See the special issue of *Development and Practice* edited by Cornwall (2007, volume17: 4-5).

the "multiple guises (the) words have assumed and . . . the dissonant agendas that they embrace" (Cornwall 2007: p. 471). According to Mosse and Lewis, the use of buzzwords helps to suture "the striking incongruence" between the "seductive" language of development and the "striking lack of progress" of development initiatives (Mosse and Lewis 2006: p. 8).

Biofuel Policy

India's current biodiesel policy bears strong resemblance to previous wasteland development schemes. The policy was first initiated in 2003 when the Planning Commission advocated establishing a National Mission on Biodiesel to help address the country's growing dependence on fossil fuel imports (Government of India 2003). The Commission further stipulated biodiesel promotion would help address the problems of climate change and rural poverty.

The Planning Commission advocated planting Jatropha on 17.4 mha of wastelands (5.3% of India's geographic area) in order to achieve a 20% biodiesel blending target. While the report does not comment on the extent of overall wastelands in the country, the report asserts planting Jatropha on wastelands will help arrest land degradation and contribute to India's environmental and rural development goals by "greening" marginal lands and providing jobs and new market opportunities to the rural poor. The current biofuel policy maintains the 20% blending goal but recommends the use of non-edible oilseeds (GOI 2009). Yet, as Jatropha is the most commercially developed non-edible oilseed, it will likely play a substantial role in the current policy. Neither the 2003 Planning Commission report nor the current biofuel policy give any guidance on how wastelands will be selected for biofuel cultivation. Lastly, the current policy establishes the National Biofuel Coordination Committee chaired by the Prime Minister to oversee biofuel production in the country.

Table 2.1: Wasteland Development Policy Recipe

				Government Initiative			
Era	**Date**	**International Influence**	**Crisis**	**Agency/ Mission Formation**	**Wasteland Assessment**	**Development Targets**	**Buzzwords**
Colonial period					1/3rd of the country		
Food Security	1947-1970	Green Revolution	Famines	Statement of Agriculture and Food Policy in India 1946			
Social Forestry	1970s	Social Forestry	1970s oil crisis the "Other" energy crisis	National Commission on Agriculture	175 mha		energy security, poverty alleviation
Rural Development	1980s		links between degradation and natural disasters	National Commission on Floods; Commission for Additional Sources of Energy; National Remote Sensing Agency (NRSA); National Wasteland Development Board (NWDB)	55.4 mha (NRSA) 130 mha (NWDB)	rehabilitate 5 mha of wastelands per year 33% afforestation	poverty alleviation, environment

Watershed Development	1990s	Community Based Natural Resource Management	land degradation and soil erosion	Hanumantha Rao report; Dharia Committee report	175 mha (Dharia report)	33% afforestation	participation, community, poverty alleviation, natural resources
Biodiesel	2000s	Kyoto Protocol, Climate Change	energy security, climate change	National Mission on Biodiesel; National Biofuel Coordination Committee	47.2-55.6 mha (NRSA estimates)	17.4 mha of Jatropha on wastelands; 20% biodiesel blending target	energy security, poverty alleviation, climate change

Outcomes

As has been well documented elsewhere, the various wasteland development schemes have repeatedly failed to meet their stated policy objectives (Agarwal 1986; Farrington, Turton et al. 2000; Kerr 2002; Saigal 2011). In addition to not meeting afforestation targets, the schemes have provided negligible rural development benefits.

In some instances, social forestry programs both within India and across the developing world reduced the extent of common land due to elite capture (Agarwal 1986; Jodha 2000). Along this line, enclosing the commons was linked to famines during the Colonial period (Satya 2004). Further, tree planting schemes on the commons often failed to mature because it was unclear how benefits would be shared (Saigal 2011). Villagers frequently uprooted trees in such instances.

Additionally, due to limited participation, it was often unclear whose interests were represented in participatory decision making programs such as watershed development (Farrington, Turton et al. 2000; Kerr 2002). In addition, tree species selection was better suited for industrial purposes rather than as fuelwood or fodder (Shiva 1991). In some cases, panchayats sold proceeds from such tree plantations but did not redistribute benefits within communities (Saigal 2011).

Explaining Repeated Outcomes: Wasteland Assessments and Perceptions

Previous research on wasteland development has primarily focused on specific programs and has not systematically looked for themes across programs. In what follows, I present two hypotheses to explain why wasteland development programs have repeatedly failed to meet their stated objectives: deficiencies in wasteland assessment procedures and differing perceptions of wastelands amongst stakeholders that are not translated into policy documents. To analyze these themes, the history of wasteland assessment is briefly reviewed followed by a case study of wasteland perceptions in the context of Jatropha promotion in India.

Wasteland Assessment

The concept of wastelands, similar to that of marginal lands, simultaneously encompasses biophysical, economic, social and political dimensions. Although multiple wasteland assessment procedures exist, none include all of these dimensions. Most assessments focus on evaluating the productive capacity of lands, which speaks to the biophysical and economic characteristics. However, wastelands are often significant livelihood territories for the rural poor, which is rarely captured in assessment procedures. Further, the process of wasteland assessment is an inherently political process governed by the state, which establishes wasteland definitions and assessment procedures. In this regard, assessment processes are equally significant in terms of what is included in assessment procedures as well as what is underemphasized or omitted.

Biophysical

The biophysical dimensions of marginal lands refer to the productive capacity of lands in terms of its soil quality and land cover. Within the biofuels literature, various attempts have been made to estimate the extent of marginal lands worldwide. Such analyses utilize remote sensing techniques to estimate land use and soil cover. Yet there is little consensus on what constitutes marginal lands across studies and thus, estimates vary widely. Campbell, et al (2008) estimate 385-472 mha of abandoned agricultural land exist worldwide that can be converted to biofuel cultivation. More recently, Cai, et al (2010) estimate 320-702 mha of abandoned or degraded agricultural land exists. However, if grasslands, savanna or marginally productive scrublands are also considered, Cai, et al estimate 1,107-1,411 mha of lands exist globally for biofuel production. Tangentially related to the biofuels literature, a recent World Bank report examining rising global trends in agricultural land investment estimated 183-446 mha of underutilized agricultural lands exist worldwide. Thus, current estimates of marginal lands range from 183-1,411 mha. Yet none of these assessments screen for the livelihood or social dimensions of these landscapes.

Economic

The economic dimension of wasteland assessment and related policy implications warrants additional consideration. Most wasteland development programs, including biofuels, center on rehabilitating a portion of wastelands that can be restored to productive use. By extension, not all wastelands are equal in an economic sense as some lands would be more costly to restore than others.[32] Drawing upon the economic concept of a marginal unit, attention thus focuses on the "marginal" portion of wastelands, the units of land that would be the least costly to restore. However, it is likely this portion of wastelands is also the portion used by the rural poor for livelihood services because such lands may have some vegetative capacity or may be lying fallow. Further, what constitutes the margin is a function of technology and may change with technological advances. In this regard, the concept of wastelands is a dynamic process, which existing static assessments obscure.

Social

As has been well documented throughout the developing world, marginal lands are often used by the rural poor for fuelwood and fodder gathering (Ostrom 1990). Such lands are often common property resources but within India, wastelands can also be privately held as result of past land redistribution schemes (Jodha 1989; Government of India 2009). In his seminal work on the significance of common property lands to rural livelihoods in India, Jodha estimated common property resources contributed nearly 25% of rural household income (Jodha 1989). As my other research demonstrates, India's wastelands are also significant sources of energy provision for rural and industrial users (Chapter 1).

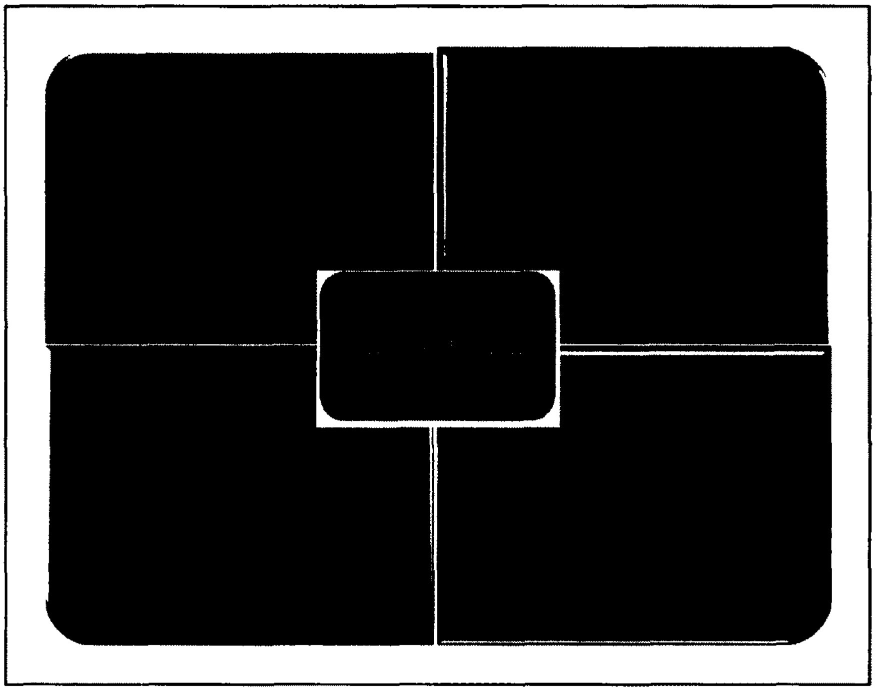
[32] Some areas classified as wastelands, such as rocky cliffs, glaciers and deserts are nearly impossible to restore.

Yet these dimensions cannot be captured by remote sensing techniques and are often de-emphasized or omitted from policy dialogues seeking to restore marginal lands.

Political

The process of wasteland assessment is an inherently political process because it is often the state that defines what constitutes wastelands and governs assessment procedures. Wasteland mapping is an example of what Scott (1998) refers to as "state simplification" as such processes often simplify the complex mix of factors that constitute such landscapes. Scott further argues such endeavors are often undertaken to help the state better achieve its policy objectives. Yet because of the simplifications such schemes often result in unintended outcomes that inhibit the state from achieving its policy objectives.

Figure 2.2: Dimensions of Marginal Lands



It is unclear how wastelands are targeted for development because the various policies, including biofuels, give no guidance. At present, there are two main wasteland assessments conducted within India. A "top down" remote sensing assessment, *The Wasteland Atlas of India* and a "bottom up" agricultural census, the Nine-Fold Classification. Both assessments differ in terms of wasteland definitions, assessment procedures and frequency. As result, both yield different results, which are challenging to compare. Further, it is also difficult to equate the same assessment historically as procedures have changed, particularly with the *Wasteland Atlas*.

Wasteland Atlas

The National Remote Sensing Centre (NRSC)[33] produces the *Wasteland Atlas of India* using remote sensing techniques. The definition of wastelands used for the Atlas hinges on both ecological and economic characteristics but also speaks to the possible causes of degradation:

"Wastelands refer to degraded lands that are currently underutilized, and are deteriorating for lack of appropriate soil & water management or on account of natural causes. Wastelands develop naturally or due to influence of environment, chemical and physical properties of the soil or management constraints."
(National Remote Sensing Centre 2010: 4)

Data is compiled by District for each State and Union Territory. Since its initial assessment in 1986, the *Atlas* has been updated three times using data from the following time periods: 1986-2000, 2003 and most recently, 2005-06. In 1986, the NRSC delineated eight biophysical categories of wastelands, which was expanded to 13, 28 and 23 in the proceeding assessments. As described in the most recent *Atlas*, it is challenging to compare across the historic categories as certain categories have been expanded or contracted while new categories have been introduced (National Remote Sensing Centre 2010).

[33] The NRSC was formerly the National Remote Sensing Agency (NRSA).

Aside from the 2010 *Atlas*, assessments were conducted using either one image from a particular year or multiple images over a long time span. The 2010 *Atlas* used three seasonal images from 2005-06 and also conducted limited ground truthing for a sample of plots. As result of the differing classification categories and data sources, wasteland estimates vary widely. In 1986, the NRSC estimated 53.3 mha (16.4% of TGA) of wasteland while the 2010 *Atlas* estimates 47.22 mha (14.91% of TGA). However, it is unclear whether this reduction is the result of rehabilitation programs or differing assessment procedures.

It is unclear what categories of the *Atlas* might be targeted for biofuel production. However, in an interview with Professor M. Ramalingam, head of the Anna University Remote Sensing Department which produces the *Atlas* for Tamil Nadu, scrublands are the likely categories for wasteland development because these lands currently support some biomass growth.[34] In the 2000, 2005 and 2010 *Atlases*[35], around 19 mha of scrublands were reported, which equates to approximately 6% of TGA.

[34] Interview 18 November 18 2010.

[35] Based on a literature review, it does not appear scrublands were not broken out as a separate category in the 1986 *Atlas*. The actual *Atlas* could not be located in a literature review.

Table 2.2: Historic NRSC Wasteland Estimates

	Atlas Year			
	1986	2000	2005	2010
Image Years		1986-88, 1991-92, 1997-98	2003	2005-06
Images Used		3 from years above	1 dry seasonal	3 seasonal
# Categories	8	13	28	23
TGA (Mha)	325.00	316.57	316.68	316.70
WL Area (Mha)	53.3	63.85	55.64	47.22
WL Area (%)	16.40%	20.17%	17.57%	14.91%
% change from previous assessment		19.80%	-12.86%	-15.13%
Scrublands	10.79	19.40	18.81	18.50
Scrublands as % of TGA	3.3%	6.1%	5.9%	5.8%

Source: National Remote Sensing Centre.

Nine-Fold Classification

The current Nine-Fold Classification system was implemented after independence in 1948 and evolved out of the five-fold classification system used in the Colonial era (Saigal 2011). The Nine-Fold Classification introduced the concept of "culturable wastelands", which referred to "land which is capable or has the potential for the development of vegetative cover and is not being used due to different constraints of varying degrees" (Sharma 1987: 47). According to the NWDB, this included lands such as gullied and/or ravenous land, undulating upland with or without scrub, waterlogged land, saline land, shifting cultivation area, degraded forests, degraded pasture or grazing land, degraded plantations, strip lands, sandy land, mining lands and industrial wastelands (Chauhan 1987).

Culturable wastelands remains a category in today's Nine-Fold Classification but the definition has been more narrowly defined:

land available for cultivation, whether taken up or not taken up for cultivation once, but not cultivated during the last five years or more in succession including the current year for some reason or the other. Such land may be either fallow or covered with shrubs and jungles which are not put to any use. They may be accessible or unaccessible and may lie in isolated blocks or within cultivated holdings. (Directorate of Economics and Statistics 2010)

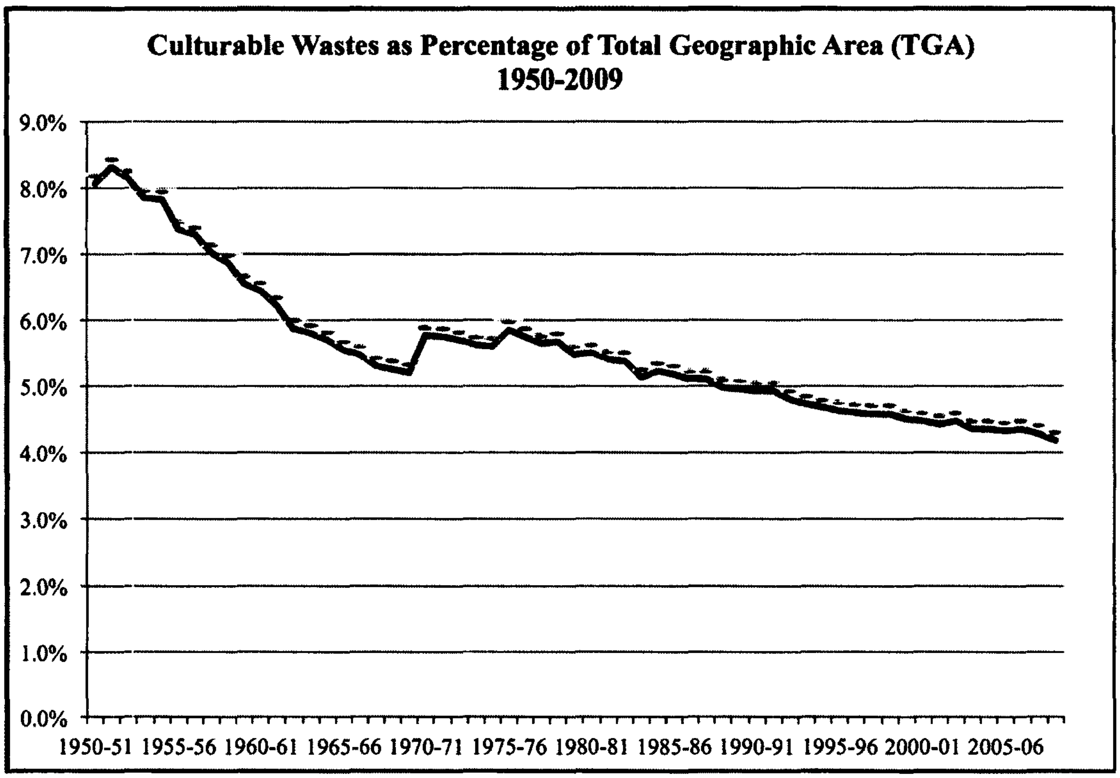
It is striking that fallow lands may be included in culturable wastelands. The designation of fallow indicates the land was productive in some capacity in the past. If the land was used for food production, this raises a host of questions about the use of wastelands for development projects such as biofuels. Could such lands be rehabilitated to again support food production? If so, a larger ethical question arises about the best use of restored lands.

The Directorate of Economics and Statistics within the Ministry of Agriculture compiles the Nine-Fold assessment annually but there is a two-year publication gap (ie. the most recent statistics are from 2008). The agricultural land use statistics are based on village land settlement records (referred to as the A Register) maintained by the Village

Administrative Officer (VAO). Settlements are conducted annually at a village-wide meeting (*Jambanthi*) held each May or June. The settlement records are passed along and consolidated at the District, State and Central government levels by the Directorate of Economics and Statistics.

Between 1950 and 2009, culturable wastes constituted an average of 5.5% of lands. As shown in Figure 2.3, the amount of culturable wastes has been in decline over this period from a high of 8% in the 1950s to just over 5% since the 1990s.

Figure 2.3: Culturable Wastelands: 1950-2009



Source: Directorate of Economics and Statistics, "Landuse Statistics at a Glance", http://eands.dacnet.nic.in/LUS_1999_2004.htm.

However, various stakeholders interviewed for this study expressed doubt regarding the validity and update frequency of village land settlement records.[36] Figure 2.3 lends some credibility to these concerns given the limited changes in the extent of culturable wastes over time. While only a limited data sample, a review of historic Nine-Fold Classifications for Virudhunagar District, Tamil Nadu[37] from 2002-2010 reveals very little change in the quantity of culturable wastes. In fact, the amount of culturable wastes is identical in four out of eight years.

Table 2.3: Virudhunagar District Culturable Wastelands, 2002-2010

Year	Culturable Waste	% Change
	ha	%
2002-03	10,063	
2003-04	9,663	-4.0%
2004-05	9,663	0.0%
2005-06	9,663	0.0%
2006-07	9,663	0.0%
2007-08	9,572	-0.9%
2008-09	9,684	1.2%
2009-10	9,543	-1.5%

Source: Tamil Nadu Director of Economics and Statistics.

Comparing the Nine-Fold Classification to the *Wasteland Atlas* is a challenge due to incommensurate categorizations. In 2005-06, the same year the 2010 *Atlas* is based on, 13.2 mha of a reported 305 mha[38] were classified as culturable waste within India

[36] Interviews with Professor K. Mahendran, Tamil Nadu Agricultural University Department of Economics, 2 September 2 2010, Dr. K. Arulmozhi, Principal Secretary/Member Secretary, Tamil Nadu State Planning Commission, 7 October 2010.
[37] This is the fieldsite region for the study.
[38] Not all states report statistics in all years. The total geographic area of India is 328.7 mha.

(Directorate of Economics and Statistics 2008: not paginated). This represents approximately 4.3% of recorded land area, about three-times less than the wasteland area percentage reported by the *Atlas* (14.91%). While closer in number to the scrubland categories of the *Atlas* (~6% of TGA), it is unclear what portion, if any, of these land categories overlap.

Further guidance from biofuel policy makers would be needed to determine whether this similarity is valid. Further, based on the introduction to the 2010 *Atlas*, it does not appear the Nine-Fold Classification is used as a data source or as a comparison point for the *Atlas* compilation (Directorate of Economics and Statistics 2010). This was broadly confirmed during interviews with government remote sensing experts in Tamil Nadu.[39] A comparison of the *Atlas* and the Nine-Fold Classification is presented below in Table 2.4.

Table 2.4: Comparison of India's *Wasteland Atlas* and Nine-Fold Classification

Category	*Wasteland Atlas*	Nine-Fold Classification
Wasteland definition	Wastelands refer to degraded lands that are currently underutilized, and are deteriorating for lack of appropriate soil & water management or on account of natural causes. Wastelands develop naturally or due to influence of environment, chemical and physical properties of the soil or management constraints	Culturable Wastes: Land available for cultivation, whether taken up or not taken up for cultivation once, but not cultivated during the last five years or more in succession including the current year for some reason or the other. Such land may be either fallow or covered with shrubs and jungles which are not put to any use. They may be accessible or inaccessible and may lie in isolated blocks or within cultivated holdings
Responsible agency	National Remote Sensing Centre, Department of Land	Director of Economics and Statistics, Ministry of Agriculture

[39] Interview with Professor Sivasamy, Head of Tamil Nadu Agricultural University Remote Sensing and GIS Centre, 3 September 2010.

	Resources, Ministry of Rural Development	
Assessment methodology	"top-down": remote sensing	"bottom up": A-Register land settlement reports compiled at village level
Update frequency	Every 5 years	Annually
Latest update	2010, based on 2005 images	2008-09
Geographic scope	National, statistics reported by district for each state	District-wise statistics for reporting states. Number of reporting states varies by year.
Wasteland area for 2005-06 (% of TGA)	14.91% overall; 5.8% for scrublands	4.5% for cultivable wastes

Wasteland Assessments and Livelihoods

In addition to the Atlas and the Nine-Fold Classification, numerous one-time wasteland classification studies have been conducted by other government agencies and NGOs. Each assessment has used different criteria and definitions and yields varied results (National Remote Sensing Centre 2010). These assessments have similarly focused on the economic and ecological characteristics of land. Absent from most these studies is an examination of the land tenure and livelihood services provided by wasteland areas.

It is generally agreed a portion of wasteland areas are also common property resources (CPRs) (for a more comprehensive review see: Government of India 1995; Eswaran 2001; Biswas, Pohit et al. 2010). In his seminal studies examining the links between CPRs and rural livelihoods in semi-arid zones in India, NS Jodha found that marginal communities derive between 15-23% of their household income from grazing animals, raising kitchen gardens and gathering fuelwood on CPRs (Chopra 2001; Kadekodi 2004).

Further, Jodha found the total area of CPRs was in decline due to population pressure and land privatization (Jodha 1986). Subsequent studies have broadly confirmed these findings for other regions of India (Pasha 1992; Singh 1996; Beck and Ghosh 2000).

The 54th Round of the National Sample Survey (NSS) assessed both the magnitude of and rural dependence on CPRs throughout the country (NSS 1999). On average, the NSS estimated approximately 15% of India's land area was CPRs and that 48% of households collected materials from CPRs. Roughly 58% of the products collected from CPRs was fuelwood (NSS 1999). These figures varied widely by geography and farmer class with Rajasthan having the largest magnitude of CPRs and landless and marginal farmers in hills and plains regions being the most dependent on CPR material collection (NSS 1999).

As evidenced by the above discussion, there is lack of agreement on the definition and extent of wasteland throughout India. Further, the ecological and livelihood services provided by these lands is under-researched. Finally, it is important to note that neither the National Mission on Biodiesel nor the National Biofuels Policy explicitly state how wastelands will be selected for biofuel cultivation and which, if any, existing assessment will be relied on. This ambiguity, combined with the lack of understanding of the multiple dimensions of marginal lands, casts doubt on the potential development benefits of wasteland development.

Wasteland Perceptions

A second possible explanation for the poor performance of past wasteland development schemes may be the differing perceptions of wastelands across stakeholders that emerges from previous literature. While the Central government issued assessments claiming large swaths of the country lie in waste (see assessment discussion above), few vacant lands were found in villages due to encroachment or subsistence use (Pathak 1994). Some scientific experts studying wasteland development asserted the concept of wastelands was a fallacy because all lands serve a purpose for man (Sharma 1987). However, these same experts glossed over the livelihood significance and historic origins of wastelands and recommended improved land use planning and mapping procedures as a way to arrest degradation (Khan 1987; Sharma 1987). Others proclaimed wastelands would be better termed "wasted lands" because of their overuse by human and animal populations (Khan 1987). This provocative assertion overlooks the origins of why and how rural communities came to occupy such spaces and does not speak to the historic ecological conditions of the lands.

Because of the similarities in policy narratives and wasteland assessment procedures between India's current biofuel program and past wasteland development schemes, a field study was carried out to assess stakeholder perceptions of wastelands. Fieldwork focused on government, corporate, civil society and village stakeholders in the southern state of Tamil Nadu, one of the leading promoters of Jatropha curcas biodiesel (GEXSI 2008) and home to a major Jatropha research center, the Centre for Excellence in

Biofuels at the Tamil Nadu Agricultural University (TNAU). Fieldwork was conducted for nine months between June 2010 and February 2011.

Field visits were conducted in Virudhunagar district (Figure 2.4) in the southern portion of the state due to high levels of Jatropha promotion in the past.[40] Fourteen villages were visited in four taluks[41] of the district (Figure 2): Rajapalayam (2), Srivilliputhur (6), Aruppukkottai (3), and Sattur (3).[42] These villages were selected because of their alleged high degree of Jatropha activity, as stated in government documents detailing the distribution of Jatropha seedlings and project funds.[43] Further, the villages were a mix of forest (5) and panchayat villages[44] (9) as Jatropha was promoted for cultivation on both forest and agricultural lands.

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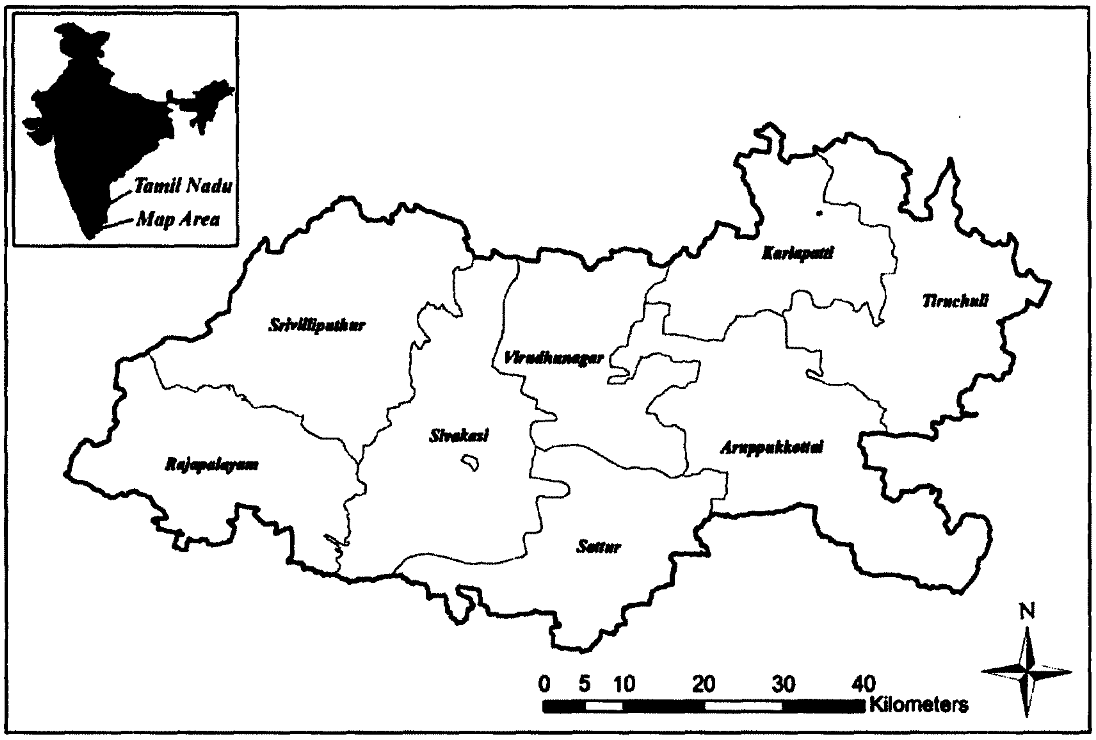
[40] At the time of fieldwork, the Jatropha economy was stalled but at least five Jatropha companies were operating in the district during previous field visits in 2008-09.
[41] A taluk is an administrative unit in India in charge of revenue collection.
[42] The names of the villages are withheld to protect the identities of informants.
[43] No database exists on the location of Jatropha activity in the state. The villages visited were selected purposively as government documents indicated they were main activity centers. Fieldwork for additional studies also focused in these regions, particularly Sattur taluk.
[44] A panchayat is a second administrative unit in India in charge of program administration.

Figure 2.4: Virudhunagar District, Tamil Nadu



Additionally, 32 semi-structured interviews were conducted with key stakeholders in the District, in the state capital of Chennai and in Coimbatore, the location of TNAU (Table 2.5).

Table 2.5: Summary of Semi-Structured Interviews

Affiliation	Department/ Description	# Interviews Conducted
District government	Forestry	4
District government	Agriculture	5
District government	District Collector's Office	3
State government	Planning Commission	3
Jatropha companies	Interviews with biofuel company officials and employees	4
NGOs	DHAN Foundation, MS Swaminathan Research Foundation, ODAM	6
Academia	Tamil Nadu Agricultural University, Anna University, Madras Institute of Development Studies	7
TOTAL		**32**

Findings

Many of the same perceptions from past wasteland development schemes still hold today. However, what emerged was a semblance of consensus amongst state-level stakeholders that contrasted from central government conceptions. State-level stakeholders were united in a belief that there are no such thing as wastelands. However, the corollary to this statement differed greatly and linked to the perceptions that emerged in past wasteland documentation.

Government Officials

Government officials frequently remarked, "there is no such thing as wasteland, only wasted land".[45] When asked to explain this comment, the officials stated areas classified as wastelands are not economically profitable to farm and should be put to more productive uses. While recognizing the ecological and livelihood significance of wasteland areas, one official went on to remark, "money and power dictates (in land assessments), not ecology".[46] When asked for clarification on wasteland assessment procedures, after detailing the mechanics of the Nine-Fold Classification, the same official stated, "wastelands are whatever the government says they are." Thus, in theory, it is possible that any land the government chooses regardless of its economic, ecological or livelihood importance could be deemed wasteland.

Village Stakeholders

At the village level, numerous officials also claimed there is no such thing as wasteland because all lands are currently in use supporting the welfare of the village. Many village lands classified as wastelands are cultivated with Prosopis, which is used for fuelwood and as a feedstock for a host of energy applications, as detailed in Chapter 1 of this thesis.

[45] Interviews with Tamil Nadu Planning Commission officials, 7 October 2010.
[46] *Ibid.*

Further, as various stakeholders remarked, Prosopis cutting is a main source of employment for the landless poor and marginal farmers.

Additionally, aside from the under-emphasis on the social dimensions of wastelands, village interviews highlighted another complication of assessment procedures. The term wasteland is ambiguous because it appears in at least three different village land assessments relating to the land tenure status, soil quality and irrigation status. While there are distinct Tamil words for each classification, *poramboke* (common land), *tharisu* (cultivable wastes) and *punjai* (non-irrigated land), villagers and some village government officials used the term "wasteland" to refer to all three conditions.

Further, the categories do not necessarily overlap as *tharisu* and *punjai* lands can be privately held. However, village officials initiated efforts to cultivate Jatropha on all three types of wasteland. This ambiguity may have helped facilitate "land grabs" of privately-held wastelands (Baka 2011). Interestingly, one government official in neighboring Theni district referred to cultivation schemes on *poramboke* lands as "propaganda schemes" meant to encourage farmers to take up Jatropha on their private lands.[47]

Villagers interviewed took issue with referring to *tharisu* lands as waste. Lands often became *tharisu* after Prosopis invaded, which occurred if a farmer was unable to cultivate for a few seasons. Villagers did not perceive such lands as wasted because their productive capacity could likely be restored if the Prosopis were removed. However,

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[47] Interview with Chandrashakar, District Rural Development Agency Officer, Theni District, 27 August 2010.

farmers were often unable to remove the Prosopis without machinery and could rarely afford these costs. Yet, as documented elsewhere, various government assistance programs were in place to assist companies clear Prosopis to cultivate Jatropha (Chapter 3).

Jatropha was planted on irrigation tank shores in many of the panchayat villages visited. Such lands are often *poramboke* lands. In one such village, the panchayat president confided he was forced by the business development office (BDO) to find land to plant Jatropha after he protested there was no space available for growing Jatropha. The village planted Jatropha along the tank shores, which villagers have historically used for cattle grazing. The president claimed Jatropha has not interfered with grazing but this may be because the shores are also densely cultivated with other tree species from past wasteland development schemes. In other villages, Jatropha was planted as a boundary fence on main roadways in town or near the panchayat offices. In all but one village, the trees along the shores and in the boundary fences had not been maintained. There was no evidence of pruning, a technique used to encourage branching and increase seed yields, and many of the trees were dried up.

Biofuel Companies

Biofuel companies operating in the region asserted they were improving rural livelihoods by putting wastelands to a more productive use through clearing the Prosopis. In fact, I first learned about the Prosopis energy economy in a 2009 interview with the General

Manager of Emami Biotech.[48] In 2008, Emami Biotech began leasing contiguous plots of wastelands from absentee farmers in Virudhunagar to raise Jatropha plantations; a process the General Manager called "contract farming under captivity".[49] However, by 2010 Emami had paused its Jatropha activities and as a possible validation of villager claims that food could be grown on lands invaded by Prosopis, was instead growing legumes on the leased wastelands.[50] While the company acknowledged the linkage between wastelands and rural livelihoods, the General Manager claimed its significance has been steadily diminishing because of the introduction of LPG gas for cooking, rural-urban migration and the National Rural Employment Guarantee Act (NREGA).[51]

According to the General Manager, Emami was also improving livelihoods by providing new employment opportunities. However, the validity of these claims is questionable because charcoal and brick kilns that use Prosopis as a main feedstock are commonly found throughout the Virudhunagar countryside and women carrying headloads of Prosopis fuelwood line roadsides at sunset each evening. Further, based on fieldwork interviews (Chapter 1) Prosopis cutting, charcoal and brick manufacturing provide about nine-months of annual employment for villagers while Jatropha offers one-time opportunities at the point of initial cultivation. Depending on if and how long a company maintains Jatropha, occasional seasonal employment for weeding, pruning and harvesting may also be available. I observed a harvest at an Emami plantation harvest in a

[48] Interview with Emami Biotech General Manager, 16 March 2009.
[49] *Ibid.*
[50] Interview with Emami Biotech General Manager, 21 June 2010.
[51] Interview with Emami Biotech General Manager, 16 March 2009. The NREGA provides 100 days of employment for Rs. 100 per day to all adult members of qualifying rural households.

neighboring district. The company hired 26 older women in theirs 50s and 60s for 15 days to harvest a 400-acre plantation. Although Emami is not actively maintaining this plantation, the harvest supervisor indicated this would be representative of the labor requirements for an actively managed plantation.[52]

NGOs

The three NGOs interviewed for this study were all actively engaged in wasteland development issues. In fact, MS Swaminathan, founder of the MS Swaminathan Foundation, was chairman of the National Commission on Agriculture 1976. ODAM initiated Jatropha projects in the past but has now stopped its Jatropha activities. DHAN had considered initiating Jatropha projects but abandoned the idea after closer scrutiny. According to DHAN's business manager, Jatropha would be uneconomic for farmers.[53] Further, the Director of DHAN claimed villagers would be better off planting fruit trees.[54]

The NGOs repeatedly stated the importance of wastelands to rural livelihoods and were working with communities to manage land resources to improve rural welfare. In fact, MS Swaminathan underscored the importance of all lands to village livelihoods in previous writings (Swaminathan 1982). ODAM and DHAN have been particularly involved with Prosopis claiming it is a significant livelihood resource for the rural poor.

[52] Interview with Mr. Nahal, 23 Janauary 2011.
[53] Interview with DHAN Business Manager, 26 June 2010.
[54] Interview with DHAN Chief Executive, 26 June 2010.

ODAM works extensively with charcoal producers in Tiruchulli District (Figure 2) and has recently initiated biochar programs using Prosopis. Despite their recognition of the importance of Prosopis, it is interesting that ODAM engaged with Jatropha. Further, despite acknowledging Jatropha as a failed experiment that may have led to "land grabs" in the region, ODAM's Director claimed that improved seed technology was the key to Jatropha's future.[55]

In a 2009 interview, Viren Lobo, Director of SPWD offered perhaps the most nuanced assessment of Jatropha, which also speaks to the heart of inaccurate conceptions of wastelands. "Jatropha can work in certain situations but not at the scale or form originally envisioned. There is no standard approach or miracle solution. It will settle down but not at the scale originally envisioned. "[56] Thus, wasteland development can meet its objectives but it will require assessments of local conditions as not all wastelands will be the same nor be equally significant to rural livelihoods throughout the country. Further, restoration and development will require locally appropriate solutions specifically tailored to meet local needs.

Discussion

This paper has examined the political construction of wastelands through an examination of present day biofuel promotion and past wasteland development schemes in India. Previous wasteland development efforts have repeatedly failed to meet stated policy

[55] Interview with ODAM Director, 7 November 2010.
[56] Interview with Viren Lobo, Director, SPWD, 20 August 2009.

objectives and India's current biofuel policy appears headed in the same direction. Yet more important than whether a program fails is an examination of why and how such outcomes are produced. I argue the concept of wasteland itself is at the root of these outcomes as the term has not been sufficiently critiqued. The discursive power of the term "wasteland" has resulted in recycled policy narratives that present these spaces as empty, underutilized or unproductive spaces utilized by unproductive peoples. Yet this stands at odds with existing uses of such spaces and stakeholder perceptions of wastelands, which are united in a belief that there are no such thing as wastelands.

Explaining the gap between policy and practice has long been of interest to political ecologists. I argue a repeated "policy recipe" occupies this space between representations of wastelands in policy documents and on the ground realities. Backed by assessments alleging significant swaths of the country are lying in waste, wasteland development policies advocate extending agriculture and forestry into wastelands as the best solution to the crisis wasteland development policies are intended to address. Yet these assessments focus primarily on the biophysical and economic capacity of lands, which obscures the social dimensions of such landscapes. The rural poor often depend on access to such lands to meet subsistence needs and my other research has demonstrated that India's wastelands are significant sources of energy provision for rural and industrial users (Chapter 1). Failing to incorporate these social dimensions into wasteland assessment increases land use pressures, which can lead to conflicts (Martinez-Alier, Kallis et al. 2010). Such pressures can also lead to exclusions as numerous studies throughout India have documented how rural elites have gained increased control over wastelands in past wasteland development schemes (Agarwal 1986; Chen 1993; Saxena 1994). My other research on the linkages between India's biofuel promotion and land acquisitions broadly confirms these findings (Chapter 3).

Yet the political dimension of wastelands is perhaps the most significant factor in wasteland development policy. The state governs this process through its power to define wastelands, establish assessment procedures and implement policies. As an examination of past wasteland development schemes and fieldwork for the current biofuel policy demonstrate, the state has historically defined wastelands ambiguously, which vests the state a degree of malleability with which it can tailor definitions and assessments to best meet policy objectives. With origins in the 16th century writings of Locke, the state has constructed wastelands as empty, unproductive spaces in need of development (often through privatization). Absent from this representation is the livelihood significance of these landscapes as well as the fractured stakeholder perceptions on the concept of wastelands. It is these factors that impact policy implementation and may help to explain why wasteland development policies have repeatedly failed to achieve stated policy objectives.

This paper has critically examined the discursive power of wastelands and unveiled the fractured perceptions and omissions underlying the representation of these landscapes in policy. Before India and other countries proceed with another round of wasteland/marginal land development in the form of an improved biofuel cultivar or otherwise, it is hoped this paper will encourage policymakers and all parties interested in promoting biofuels or similar marginal land development policies to first reassess the concept of wastelands before advocating new projects in these spaces.

Chapter 3. The Political Construction of "Wasteland": Wasteland Development, Land Acquisitions and Social Inequality in South India

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Abstract

Through a micro-level study of a biofuel-related land acquisition in rural Tamil Nadu, India, this paper reveals how state subject relations are shaping modern land deal politics. Through its political construction of the concept of "wasteland" and its associated wasteland development program, the Indian state has facilitated a series of questionable land acquisitions, shaping agrarian livelihoods in the process. A class of land brokers has emerged to help carry out the state's project of converting "wastelands" to more "productive", state-defined uses such as biofuel cultivation or industrial expansion. Those whose lands have been acquired as part of these programs have increased their transition to wage labor, increasing the prolitarianization of agrarian communities. By documenting the mechanics of this "wasteland governmentality", this paper contributes to a political sociology of the state by unpacking the linkages between the state and agrarian subjects in the context of the "global land grab". Understanding these linkages will help enhance portrayals of the state within this literature and help develop more cogent strategies for reducing excessive land appropriations.

Introduction

In 2005-06, land brokers in the Sattur region of southern Tamil Nadu, India began approaching local farmers asking to buy their privately owned "wastelands". Due to repeated droughts and on-going shifts away from agriculture, farmers in this region had reduced cultivation activities or abandoned their lands in recent years rendering the spaces "wastelands" in the eyes of the government. The brokers offered a solution: sell the lands to help a North Indian company set up a Jatropha biodiesel plantation. However, once farmers started to sell some plots, the brokers were able to obtain land records of neighboring plots without the owner's knowledge or consent through collaborations with local government officials. After acquiring 800 acres by early 2007, the biofuel company planted Jatropha on about half the area but abandoned the plantation two years later before one seed was ever harvested. They started selling the land to real estate developers, which has reduced the extent of potentially arable lands in the region, raising questions about how agrarian communities can provision for themselves. Government valuations of the plantation lands have increased by 43% per acre from the time the biofuel company initially acquired the lands to when the company sold the land into real estate. Affected farmers, who have received little to no help from government officials or civil society advocates, have accelerated their transition to wage labor in nearby factories. In some instances, they, like many other farmers in the region, have become land brokers themselves hoping to move from field to office, thus increasing their social status, just as Pothiraj, the main land broker facilitating the biofuel plantation, had done.

This deal is emblematic of the larger process of agrarian change taking place in Tamil Nadu and elsewhere throughout the world due to increased competition for land to achieve climate change, energy, food, and industrialization policy objectives. The World Bank estimates approximately 200,000 to 775,000 million hectares (Mha) is available and "suitable"[57] for such projects (World Bank 2010). The "explosion" of land deals that has resulted in recent years as result of these policy shifts has been popularly dubbed the "global land grab" (Borras, Hall et al. 2011). Although estimates of the extent of land taken up to date vary (Introduction to this issue), the World Bank calculates about 40,000 Mha of land transactions took place between 2008-09 (Arezki, Deininger et al. 2011). Yet project implementation "remains limited" with few of the transacted lands being used "as intended" in initial project documents, raising concerns about land speculation (Deininger 2011: 24).

Research analyzing the mechanics of these deals and how the acquired land is being used is just starting to emerge. Grounded in Foucault's (1991) theory of governmentality and using the Sattur land acquisitions as a case study, this article examines how the relationship between the Indian state and its agrarian subjects is shaping modern land politics in India. Through its long-standing project to convert wastelands to more "productive" uses, the state set the conditions to facilitate the land deals. Entrenched

[57] Defined as agriculture and forest lands that are currently non-cropped and non-protected with population densities ranging from $<5/km^2$ to $<35/km^2$.

conceptions of wastelands and classification techniques construct the lands as empty, unproductive spaces available for development. Yet, these processes obscure the existing land use patterns and in this case, owners of the lands.

In response, upwardly mobile villagers have become land brokers to facilitate the state's project. While the company acquiring the lands did not utilize it as intended, the project nevertheless achieves the state's ultimate goal of reducing the extent of wastelands. This helps explain why little action has been taken to contest the unanticipated conversion of agricultural land to real estate occurring throughout the state. It further explains why farmers whose lands were taken without their knowledge or consent and who have not become land brokers have received little government assistance. This class of farmers has responded by increasing their time as factory wage laborers. Although this transition was already in progress, these deals likely accelerated the pace, reducing the time and means available to farmers to manage this transition. Thus, through the disciplinary technique of wasteland development, the state has shaped an emerging class of land brokers and accelerated an on going process of proletarianization.

As a further theoretical contribution, this paper contributes to a political sociology of the state in the context of modern land deal politics (Introduction to this issue). More specifically, this analysis complicates the World Bank's portrayal of land grabs as occurring primarily in corrupt countries and that improved governance would help alleviate land grabs (Introduction to this issue). On paper, India's governance of wastelands is sound and the land acquisitions appear to be legal. Yet the governance process is entirely state controlled and obscures the realities of land users on the ground. Additionally, the Sattur study reveals how this concept is a political construct of the state that has been mobilised to facilitate land acquisitions without farmer knowledge or consent. It further demonstrates how the concept has been shaping relations between the state and agrarian subjects since Colonial times. Thus, reducing the extent of land grabs will require qualitative analyses of the power relations shaping land use policies, which will better isolate the role of the state in shaping land deals.

After a theoretical review of governmentality and wasteland development, the field site is introduced followed by a review of current wasteland policies in India. The land deal mechanics are then presented followed by a concluding discussion focused on the theoretical contributions of the paper.

The State and Subject Formation

In his theorizing on state-subject relations, Foucault (1991) coined the term "governmentality" to refer to the processes states use to shape the conduct of its citizens. This system of governing, which emerged in the 18^{th} century, consists not just of government institutions and agencies but more importantly of the discourses, norms, identities and disciplinary techniques states use to legitimize a practice of government (Gordon 1991). Underlying this "rationality of government" (Gordon 1991: 3) is a "microphysics of power" (Foucault 1979) forging relations between state and subject. Hence, government, according to Foucault, is "the conduct of conduct" (Dean 1999: 10).

Analyzing government requires the evaluation of practices of government and how the power relations between state and subject are formed. Foucault argues that government is both "totalizing" and "individualizing" (or "vertically encompassing" (Ferguson and Gupta 2002)) in that states set conditions for "appropriate" behavior that populations internalize and use to self-govern (Foucault 1983). Thus, while the state might be physically absent on the ground, its projects still function to shape subjects. Yet the relations between state and subject are not top-down. The individualizing characteristics of governmentality create space for subjects to "imagine" the state's projects (Agrawal 2005) and respond in manners that best meet subjects' needs. This could be through resistance (Scott 1985; Agrawal 2005) or, in the case examined herein, through reinterpreting the state's project to achieve social mobility.

Wasteland Governmentality

The term "wasteland" dates back to Locke, who used the term to refer to uncultivated common property lands. Arguing "the provisions serving to support human life, produced by one acre of inclosed (sic) and cultivated land are...ten times those which are yielded by an acre of land...lying waste in common" (Locke 2011 (1680): sect. 37), Locke advocated for privatizing wastelands as a means of improving societal welfare. Highly influential in shaping property regimes, Locke's "waste-value-property-triad" rested at the heart of the Indian colonial endeavor (Gidwani 1992).

In Locke's view, land ownership was also a requirement for citizenship. However, this right to ownership was not inalienable for even enclosed lands could be classified as waste and targeted for redistribution or sale if not put to productive use: "But if either the grass of his enclosure rotted on the ground, or the fruit of his planting perished without gathering…this part of the earth, notwithstanding his enclosure, was still to be looked on as waste, and might be the possession of any other" (Locke 2011 (1680): sect. 38). Thus, for Locke, maintaining the productive capacity of lands triumphed.

Yet, the concept of wasteland also contains a moral dimension. Locke posited property is a natural right bestowed by God (Locke 2011 (1680)). To waste land was thus immoral (Gidwani 1992). Such reasoning permeates Indian Colonial records, which portray Indians as inferior to their British colonizers on account of their lack of private property rights (Gidwani 1992). The concept was also used to divide Indians during the process of establishing Colonial forest policy (Whitehead 2010). Land owners, who were typically caste members, were considered "civilized" while wasteland users, typically tribal members, were considered "savage". A further goal of forest policies and colonial wasteland development was thus to convert the "savage" into "civilized" by implementing a system of private property rights.

These principles formed the basis of India's wasteland development program, which started in the Colonial era and persists to this day through the country's biofuel and industrialization policies. Operationally, the various wasteland development programs have attempted to reduce the extent of wastelands either by extending cultivation or tree planting onto wastelands or by redistributing underperforming lands. Although the policy objective of wasteland development has shifted over time from improving food security in the 1970s to the current program of improving energy security through biofuel production (Saigal 2011), the underlying rationale of the program has remained fixed: improve the productivity of lands by converting "waste" into "value" and in the process, convert the "savage" into the "civilized".

In this regard, the concept of wasteland is a political construct, which helps to explain why the concept is not easily defined. At present, multiple, competing definitions of the term exist within India primarily focusing on the ecological, economic and biophysical conditions of landscapes (Gidwani 1992; Eswaran 2001). Yet, despite this ambiguity, the term is universally constructed as something "bad" that should be eliminated (Gidwani 1992). The negative connotations of the term also awards it a degree of political malleability as it is hard to argue against eliminating waste (Ariza-Montobbio, Lele et al. 2010). This contributes to the state's ability to continually redefine its wasteland development objectives making it difficult, if not impossible, to determine what constitutes wasteland.

Further, multiple, incommensurable wasteland assessment procedures currently exist, which use agricultural statistics or remote sensing assessments as the basis of analysis. Positing that large swaths of the country are wastelands, these techniques provide further impetus for wasteland development. At present, two main wasteland classifications exist, the Nine-Fold Classification and the Wasteland Atlas of India. Each classification uses different definitions and assessment methods, leading to different results that cannot easily be compared.

The Nine-Fold Classification, compiled annually by the Ministry of Agriculture, sorts lands into nine different categories depending on their current land use. Data is presented at the district level in each state. The assessment contains two wasteland classifications: cultivable wastes and uncultivable wastes (Directorate of Economics and Statistics 2010). Cultivable wastes are lands that have not been cultivated in the last five years but were cultivated at some point in the past. Uncultivable wastes have never been cultivated and include land types such as deserts and rocky lands. Cultivable wastes are the relevant category for the Tamil Nadu land acquisitions. In 2007-08, approximately 4.3% of India's land area was classified as cultivable waste (Directorate of Economics and Statistics 2010). Within Tamil Nadu, 2.3% of Virudhunagar District's land area (the district of the study site) was classified as cultivable wastes, compared to a state figure of 2.7%.

The Wasteland Atlas of India, funded by the Integrated Watershed Development Programme (IWDP) is conducted by the National Remote Sensing Centre (NRSC).[58] The NRSC uses remote sensing techniques to categorize wastelands into 23 different categories based on the ecological characteristics of the land (National Remote Sensing Centre 2010).[59] Data is compiled by District for each State and Union Territory. The

[58] The NRSC is also housed within the Department of Rural Development.
[59] The eight broad categories are: gullied/ravenous land, scrubland (with or without scrub), waterlogged and marshy land, land affected by salinity/alkalinity, shifting

Atlas is updated every 5 years using remote sensing images captured five years prior to the date of publication (ie. the 2010 Atlas is based on 2005 data). Classifications are made by comparing three seasonal images of each plot taken over the course of one year. In addition, limited ground truthing is conducted for a sample of plots. According to the most recent Atlas, approximately 15% of India's total land area is wasteland. Within Tamil Nadu, just over 7% of the state is classified as wasteland while 3.8% of land in Virudhunagar is classified as wasteland.

Yet such classification procedures often simplify or obscure the more complex realities that exist on the ground (Scott 1998). Neither the Nine-Fold Classification nor the Wasteland Atlas consider land tenure status or *de facto* land use patterns, which can lead to overestimates of the extent of wastelands. As is widely known, the rural poor often depend on common property lands for subsistence (Ostrom 1990). Within the land grab literature, other researchers examining land transactions have found that lands classified as "empty" or "unused" by governments are often utilized by local communities (Borras Jr. and Franco 2012). The wastelands of Tamil Nadu examined in this study were formerly overgrown with Prosopis juliflora (hereafter Prosopis), a non-native acacia tree species introduced in the 1970s during Social Forestry, a previous state sponsored wasteland development scheme (Arnold, Bergman et al. 1987). Prosopis currently provides multiple energy services to rural and urban consumers as it is widely used as an

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cultivation, scrub forest (underutilized, notified forest land), sands (coastal/desert/riverine), mining/industrial wastelands.

energy feedstock for household fuelwood, charcoal production, small-scale manufacturing and electricity generation.[60]

As this paper reveals, the state's wasteland development program obscures the diversity of wasteland landscapes constructing them as "empty", "available" spaces available for the state's land use projects. This obfuscation has shaped an emerging class of land brokers who, through the process of internalizing the state's wasteland development project, have helped the state reduce the extent of wastelands, increased their social status and exacerbated the prolitarianization of agrarian communities.

Methods and Field Site

Fieldwork took place from June 2010 to February 2011 in twelve villages in Sattur taluk, Virudhunagar District, Tamil Nadu (Figs. 1 & 2). Fieldwork examined the mechanics of an 800-acre Jatropha land acquisition by New Delhi-based T. Shivaleekha Biotech (hereafter Shivaleekha) that occurred beginning in 2005.

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[60] These observations are from additional fieldwork I have conducted in this region. We find that Sattur's Prosopis economy provides approximately 4-15 times more useful energy to the region than would Jatropha biofuels ('Marginal lands and energy security: A comparison of biofuel and biomass energy services', Baka, J., Bailis, R., Jain, G., Shenoy, M., poster presentation at International Society for Industrial Ecology Biannual Conference, Berkeley, CA, 7-10 June 2011.

Figure 3.1: Sattur Taluk

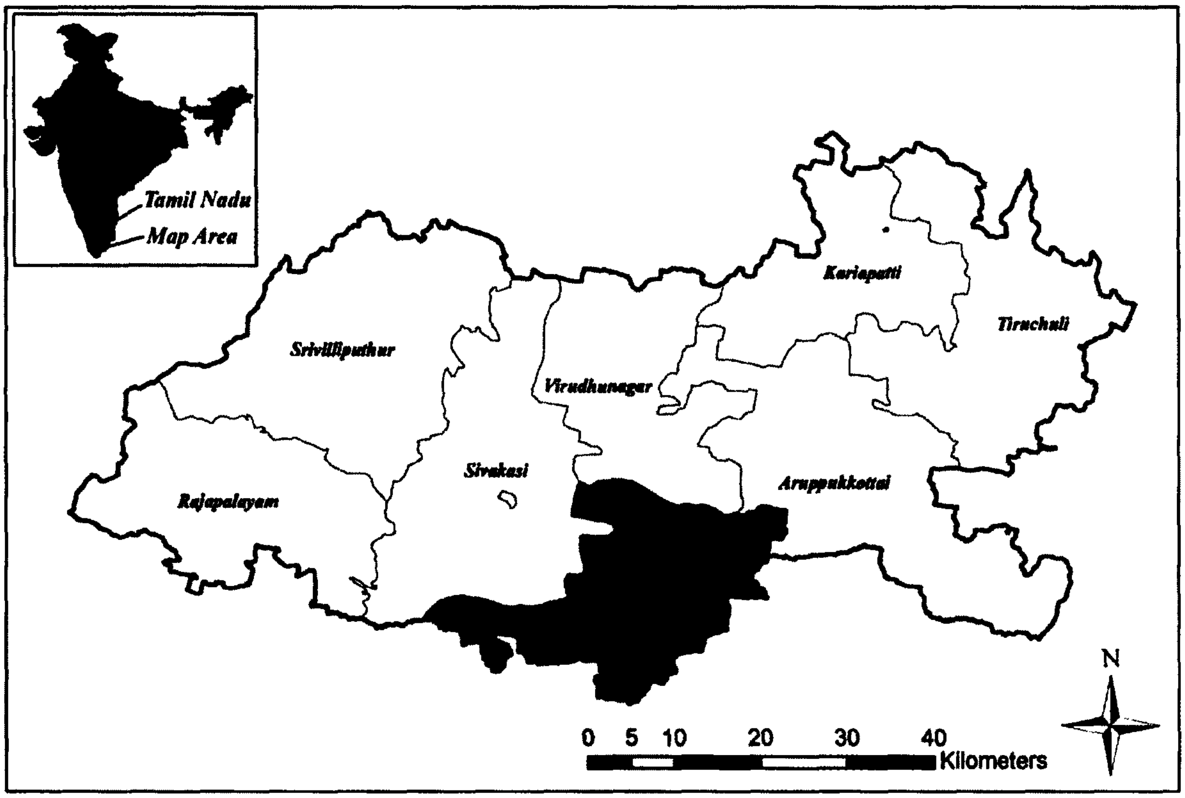
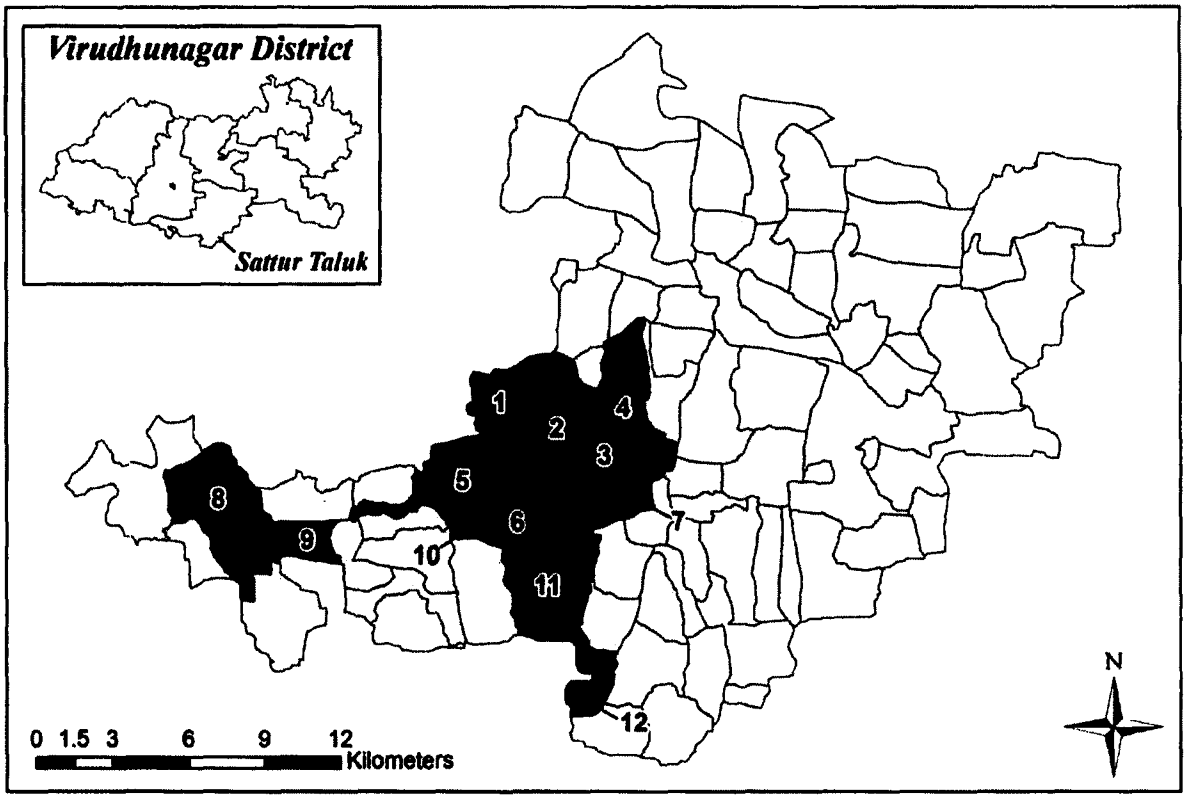


Figure 3.2: Villages Involved in Land Acquisition



Villages: 1. Banduvarpatti, 2. Soorangudi, 3. Ottiyal, 4. O. Mettupatti, 5. Kongarakottai, 6. Muthusamypuram, 7. Chinna Thambiyapuram, 8. Thulukkukurichi, 9. Sankarapandiyapuram, 10. Muthandiapuram, 11. Karasilpatti, 12. Periyampatti

Details of the land acquisition were obtained through semi-structured interviews with 48 key stakeholders and 13 farmers whose lands were involved in the acquisitions. Various land record documents, including Encumbrance Certificates (EC)[61], land sale records, tax records and *patta*[62] forms were obtained to triangulate the farmer narratives.

[61] EC records document the 24-year ownership history of a plot of land.
[62] A *patta* form is a legal recording of a farmer's land portfolio, including survey numbers and plot size.

Tamil Nadu Agrarian Status and Wasteland Policies

Tamil Nadu is one of the most industrialized states in India with the highest urbanization rate in the country (48.5%) (Government of India 2005; Government of India 2011). It also has the third highest human development index (HDI) score amongst Indian states (Government of Tamil Nadu 2003). Yet inequalities plague the state's agriculture sector.

Agriculture's contribution to net state domestic product (NSDP) has fallen to under 20% in recent years from a high of around 43% in the 1960s (Government of India 2005). Yet 60% of the state's workforce is engaged in agriculture on some basis (Government of India 2005). Per capita income in the sector has been stagnant since the 1960s (around Rs. 4,000) while the number of landless laborers has grown steadily. Presently, about 20% of the agricultural labor force is landless, the highest rate in the country (Ramaswamy 2007). Marginal farmers, those owning less than 0.25 acres, are the largest class of landholders and account for nearly 73% of all land holdings (Government of India 2005). Yet the average landholding size across farmer classes is 2.35 acres, dominated by the 53.6 acre average holding size of large farmers (those owning greater than 24.7 acres) (Government of India 2005).[63] Further, about 75% of rural households are in debt, the second highest rate in the country (Narayanamoorthy 2006).

[63] Land holding statistics are based on 1995-96 data, the most recent year for which data was available.

These factors help to explain the increased diversification out of agriculture observed throughout the state in recent years (Djurfeldt, Athreya et al. 2008; Vijayabaskar 2010). Mirroring patterns observed throughout the country (Shah and Harriss-White 2011), farmers are engaged in a "diffused process of urbanization" (Vijayabaskar 2010: 38) through short-term or seasonal migration to urban areas, which has lead to agricultural labor shortages. Similar patterns were observed in the study region as farmers and laborers have taken up work at the growing number of paper and fireworks factories that have opened in recent years. In some families in the Sattur region, younger generations have also migrated to the Middle East for work. As result, agricultural laborers have started demanding higher wages and transportation to farms, which has motivated some farmers to abandon their agricultural lands.

In light of these structural shifts in agrarian society, some farmers have begun selling lands in recent years. As the next section will demonstrate, the land sales are intimately linked to the state's broader wasteland development policies.

Wasteland Development Redux

Various policy developments at the state and central government level set the conditions for the land transactions in rural Tamil Nadu. The 2005 Tamil Nadu Development Report, prepared by the Planning Commission of the central government and used to set policy priorities in the state, identifies wasteland development as a central priority needed to improve land productivity and to provide employment to the "growing army" of landless laborers (Government of India 2005). Simultaneously, the central government established its own wasteland development agenda through its biofuel (Government of India 2003) and climate change (Government of India 2008) mandates, both of which aim to "develop" wastelands by establishing biofuel feedstock or tree plantations on these areas.

In 2003, the central government began a National Mission on Biodiesel, which advocated planting Jatropha on 33 million acres of wastelands throughout the country, equivalent to 4% of India's total geographic area. Tamil Nadu has been a key player in the program, developing a Jatropha research institute at the Tamil Nadu Agricultural University and initiating a state level biofuel program that supported Jatropha cultivation through leasing wastelands to companies (Government of Tamil Nadu 2002), granting two acres of wastelands to the rural poor (Government of Tamil Nadu 2006) and through contract farming (Government of Tamil Nadu 2007). A 2008 industry survey found that India in general and the state of Tamil Nadu in particular were the world's leading cultivators of Jatropha (GEXSI 2008).[64]

In addition to the state's land concessions highlighted above, both the central and state government provided various support mechanisms to support biofuel production on wastelands. The central government subsidized the cost of labor through its National Rural Employment Guarantee Scheme (Government of India 2005), established minimum support prices for biofuels, and assisted with project financing through its

[64] The GEXSI study surveyed Jatropha companies via phone and internet. Limited ground truthing was conducted, raising questions about the validity of the findings.

agricultural development bank (Government of India 2003; Government of India 2008). Additionally, the state government subsidized the cost of planting materials (Government of Tamil Nadu 2007) and land clearance[65].

Around the same time that the biofuel program was initiated, the state government enacted a Special Economic Zone (SEZ) Act to promote industrialization throughout the state. The alternative name of the act stated in the body of the legislation underscores the importance of land in the state's industrialization program, the "Tamil Nadu Acquisition of Land for Industrial Purposes Act", which is actually an amendment to a 1997 Act of the same name (Government of Tamil Nadu 2005). Through these acts, the government began amassing a land bank through various government agencies and allowing private industries to purchase land directly without government approval. As is more clearly spelled out in the state's 2007 Industrial Policy, wasteland acquisitions are central to the state's industrialization goals as the state intends to "amend relevant laws and regulations [to enable] automatic conversion of dry lands from agriculture to industrial use" (Government of Tamil Nadu 2007: 12). As result, the state has eased the time requirements for land acquisitions from three years to less than 180 days and has also reduced the time and legal mechanisms available to contest acquisitions (Vijayabaskar 2010). Similar to its pioneering status in biofuels, the state is also one of the country's leading SEZ promoters with 50 SEZs established to date (Vijayabaskar 2010).

[65] Interview with Mr. Simpson, Srivilliputtur Business Development Office clerk (17 September 2010).

Because some farmers have agreed to the land sales involved in establishing SEZs, Vijayabaskar characterizes the current land deals in Tamil Nadu as a "silent process . . . secured more through a process of consent than coercion" (Vijayabaskar 2010: 42). Yet, he also observes how "real estate consultants", the middlemen encouraging farmers to sell lands, have utilized deceptive practices to motivate sales and minimize sale prices.[66] While there have been no large-scale protests to the deals, Vijayabaskar records various small-scale protests, particularly over the transfer of wastelands.

He notes how lands designated as wasteland by the state and sold did not reflect existing land use patterns or tenure status. Yet farmers have had little recourse due to their lack of clear title and limited assistance from local government officials and civil society organizations. As will be demonstrated in the following sections, the Sattur land acquisitions parallel many of Vijaybaskar's findings. However, this study better problematizes why the acquisitions are seemingly taking place in silence by unpacking how the state's wasteland development project is shaping agrarian subjects to facilitate its land use goals.

Sattur Land Acquisition Mechanics

Starting in 2005-06, land brokers for North India-based Shivaleekha began approaching farmers in the village of Soorangudi offering to purchase their wasteland holdings. After amassing a plantation of roughly 800 acres, the company is said to have planted Jatropha on roughly half the area. However, they maintained the trees for less than two years and

[66] Instead of mentioning the land sales are to create an SEZ, the consultants state the lands are needed to establish large-scale farms.

never harvested seeds as the trees could not reach maturity in this time period (Achten, Verchot et al. 2008). In 2009, they started selling off the plantation lands to real estate companies headquartered in Mumbai, Raj Green Valley Developers and Raigad Infra Projects.[67]

Accumulation

"Poor farmers can't fight" Karasilpatti farmer (not affected by the land acquisition) describing why the land acquisition is happening, February 12, 2011

The brokers offered farmers Rs. 3,000-5,000 per acre, which was well below the government guideline values (GLVs) of Rs. 9,600 per acre at the time of the acquisitions.[68] However, many farmers in this region had been unable to farm these particular lands for numerous years because of poor monsoon rains. Farmers interviewed for this study spoke of having to borrow from moneylenders in these times to make ends meet. The price offered by the brokers allowed them to repay the money lenders, a debt trap that has been linked to numerous farmer suicides in Indian agrarian society (Assad 2008).

Further, if a farmer decided to sell land, he typically did not discuss it with others as doing so is considered shameful. This secrecy may have facilitated the land acquisition because the land brokers, many of whom were from a neighbouring village, would likely

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[67] Interview with Shivaleekha land acquisition manager (11 November 2010) and EC document records.

[68] GLVs are government land value assessments. The process will be further discussed in the Land Prices section of this paper.

have been aware of this cultural practice. When the sales and resultant land acquisitions were discovered within villages, fights erupted. In one family, an elderly farmer's children refused him food for a month when they learned he had sold the family's land.[69]

In order to sell the lands, farmers had to provide their land ownership documents to the brokers so that the company could re-register the plots. Once the brokers had these documents, they would re-register the lands in one of three ways: directly in the name of Shivaleekha, in the name of a middleman or power of attorney holder who in most instances, later sold the land to Shivaleekha or in the name of MS Greenenergy, a company that later sold to Shivaleekha. The sales to Shivaleekha via land brokers or middle companies took place in a matter of days, based on a review of the EC documents.

As previously discussed, the farmer's *patta* form would list all lands registered in the farmer's name. Based on interviews with affected farmers, the *patta* form may not accurately reflect the *de facto* use of the plots. In numerous instances, a farmer's *patta* mistakenly included neighbors' lands and/or did not reflect partitions within families. In four instances in this analysis, once in possession of a *patta* form, the land brokers re-registered all the plots on the form regardless of whether the plots were purchased.

However, purchasing lands and obtaining documents from farmers was not the sole way the company acquired lands. According to villagers, the brokers frequently approached them with the requisite government land surveys and ownership details already in hand.

[69] Interview with Keela Chellaipuram farmers (5 February 2011).

These documents included the land survey map and wasteland classifications. Within the village, such records are produced by the Village Administrative Officer (VAO). In Karsilpatti (Figure 3.2 #11), the Taliari[70] and VAO were transferred for allegedly selling survey details to the brokers.[71] According to villagers, brokers supposedly paid these officials Rs. 200 for each survey obtained. As one affected farmer remarked, "without the support of the government officials this (the land acquisition) could not have been done".[72]

Equipped with the land records, the brokers could also generate false legal documents to re-register lands. This involved creating a power of attorney document whereby farmers ceded control of their lands to a designated power agent who could then sell the lands on the farmers' behalf. Generating a power of attorney document required the signatures, thumb prints and pictures of the farmers, which were easily forged, based on the experience of one such affected farmer from Ottiyal village (Figure 3.2 #3) who had obtained a copy of the forged power document used to re-register his lands without his knowledge or consent.[73] A land broker in a neighboring village generally confirmed this process for acquiring lands.[74]

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[70] The Taliari is a village elder that works with the VAO to administer village affairs. He/she has equal access to all land transaction details and must approve all land purchases and sales.
[71] Interviews with Kongarakottai affected farmers (5 February 2011). In addition, the Taliari in question has been reinstalled in the position in the village. In an interview, he confirmed he had been transferred for a period of time but did not state the reason (15 December 2010). Additionally, the VAO from Karasilpatti stated officials in Kongarakottai had been transferred because of the land deals (17 December 2010).
[72] Ottiyal farmer affected by the land acquisition (12 February 2011).
[73] *ibid.* 'General Power Documentation', 3 July 2006.
[74] Thlukkankurichchi land broker (21 January 2011).

Broker's Sales Pitch: A Lockean Narrative of Wasted Lands

According to both farmers and village officials, the brokers initially came in search of wastelands. More specifically, they approached the VAO asking for the locations and survey numbers of *tharasu* lands, the Tamil word for cultivable wastelands under the Nine-Fold Classification. The *tharasu* lands targeted by the brokers were often overgrown with Prosopis, which, as previously discussed, was introduced as part of a past wasteland development scheme. Once covered with Prosopis, farmers usually have no choice but to abandon their lands, rendering them *tharasu* as they cannot afford to clear the tree given its deep root structure. According to VAO officials, lands covered with Prosopis are often classified as *tharasu*.[75] Subsequently, that a tree formerly introduced to eliminate wastelands is now a condition for classifying lands as wastelands underscores the political malleability of the concept.

Within farming communities, the brokers approached farmers to buy their Prosopis lands asserting they could put the lands to better use by planting Jatropha trees, which could be used to produce fuel. Farmers were well aware of Jatropha as Tamil Nadu has been one of the leading promoters of the tree since the central government began promoting Jatropha biofuels in the early 2000s (Government of India 2003; GEXSI 2008). Multiple biofuel companies operated in the region (author's fieldwork) and in northern parts of the state (Ariza-Montobbio, Lele et al. 2010) to recruit contract farmers. If a farmer agreed to

[75] Interview with Karsilpatti VAO (17 December 2010).

sell, the company would remove the Prosopis and restore the productivity of the lands. At the time of the land acquisitions, the District government offered companies assistance with Prosopis removal. Farmers were ineligible for this assistance.[76] Further, four of the 13 farmers interviewed reported the brokers claimed the company only wanted to grow Jatropha on a portion of the lands and would allow farmers to continue farming the remaining portions of the plantation once the company cleared it of Prosopis.

Discovery

Farmers whose did not sell their lands found out that their lands had been appropriated in 2009-10 mainly in one of two ways. First, after another season of crop failures, the government offered relief assistance to farmers. To qualify, the farmers had to present their land documents and when the government examined the records, the farmers were told their lands were no longer in their possession.

Second, in July 2009, Shivaleekha placed an ad in a local daily newspaper, "Thinathanthi" (Daily Telegraph), announcing they had purchased lands in Soorangudi and Ayan Kongarakottai (Villages #2 and #5, Figure 2). The ad listed the survey numbers for 420 plots and asked anyone with objections to the sales to contact a lawyer in Madurai (90 km away) within seven days (anon 2009). A typist at the Sattur Land Registration Office saw the ad and informed a Soorangudi farmer who happened to be in the office that day. The particular farmer's lands were listed in the ad although he had not

[76] Interview with Mr. Simpson, Srivilliputtur Business Development Office clerk (17 September 2010).

consented to sell his lands. He took the advertisement back to the village to alert other farmers.

Land Record Analysis

To triangulate the farmer narratives, Encumbrance Certificates (ECs), which document the 24-year ownership history of an individual land survey, were obtained from farmers and the government land registration office. In total, EC records for 193 surveys related to the plantation in three villages (Karsilpatti, Kongarakottai and Sooringudi, villages #11, #2 and #5, Figure 3.2) were obtained. The total area of these surveys is 246 acres (30% of the 800 acre plantation).[77] The EC records contain 107 transactions[78] related to Shivaleekha activities: transfers from farmers to Shivaleekha (n=35), transfers from farmers to MS Greenenergy or land brokers (n=26), exchanges between land brokers (n=5), transfers from land brokers to Shivaleekha (n=10), transfers from Shivaleekha to real estate companies (n=22), lien removals (n=5) and mortgages (n=4).

These 107 transactions were examined across time to trace the transaction history of the lands transferred from farmers to Shivaleeka or land brokers. As shown in Table 1, 39 of the 61 transfers from farmers have been sold to real estate. These transactions represent

[77] The sample of surveys is not a random sample of the plantation area. It represents the subset of surveys obtained from government land registration officials in the three villages in the course of fieldwork. Thus, while the analysis in this section may not be representative of the plantation as a whole, it is illustrative of one process of land acquisitions for the plantation.
[78] One transaction often involved multiple survey numbers. Thus, the number of transactions in the EC records is less than the number of surveys.

175 acres across the three villages. The remaining 22 transfers from farmers to Shivaleeka or land brokers (71 acres) have not been sold into real estate. Lastly, Shivaleeka acquired the lands from farmers and middlemen between March 2006 and July 2007 while the sales to real estate took place between September and October 2009. Thus, the EC records confirm the farmer narratives both in terms of timing and transaction process.

Table 3.1: Summary of Shivaleeka Acquisition Transactions

	Number of Transactions	Area	Transaction Date Range
	#	acres	
Transfers from farmers to Shivaleeka or land brokers	**61**	**246**	**March 2006 - July 2007**
• Shivaleeka acquisitions sold to real estate	39	175	September - October 2009
• Shivaleeka acquisitions not sold to real estate	22	71	March 2006 - July 2007

Motivations

Various farmers and village officials alleged the company was only interested in obtaining land documents for plots in the area, not in growing biofuels. Equipped with land documents, the companies would be able to apply for bank loans using the land as collateral. According to the former plantation guard, Shivaleekha wanted the lands for *kanakku*, for namesake only. When asked to elaborate, the former guard stated the company was possibly using the land documents to get bank loans.[79] At least one farmer in each of the affected villages visited claimed the company was taking government bank loans using the lands. Ariza-Montobbio, et al (2010) documented similar linkages between biofuel promotion and government loans in northern Tamil Nadu.

It does not appear this loan motivation is a mere rumor circulating amongst villagers. The Karasilpatti VAO stated this was the key reason for the land acquisitions and the Sattur Sub-Inspector of Police, the highest-ranking police officer in the taluk, said this sort of crime happens frequently in rural India.[80] While the police officer was unaware of such land-loan deals within Sattur, he confirmed instances of corporate-sponsored land acquisitions taking place elsewhere in the District in recent years. Lastly, four land plots acquired for the plantation have been mortgaged, according to the EC documents.

The region is also at the frontier of the state's industrial expansion, indicating another possible motive for the acquisitions. The study region is located about 90 km south of Madurai, the second largest city in Tamil Nadu and home of the ELCOT I SEZ. Further, the region is approximately 90 km west of the Tuticorin port, a large international port currently undergoing expansion as part of the state's Industrial Policy (Government of Tamil Nadu 2007). Additionally, the villages are about 6-17 km west of National Highway 7, a major highway connecting Bangalore, Madurai, Tirunelveli and

[79] Interview with former Shivaleekha plantation guard (18 December 2010) who also sold 6 acres of land to the company.
[80] Interview with Karasilpatti VAO (17 December 2010) and interview with Sattur Sub-Inspector of Police (11 February 2011).

Kanyakumari. In recent years, much of the land adjacent to the highway has been cleared and demarcated for real estate development. The study site is immediately behind these real estate developments.

Outcomes: Farm, Factory and Land Brokering

"If they can't support us, we're all going to die", Kongarakottai farmer commenting on decision to approach CPM for help, February 5, 2011

Affected farmers were reluctant to go to the police for help because of the role of village government officials in facilitating the land transactions. As a second recourse, some farmers turned to their regional Member of the Legislative Assembly (MLA) for assistance. However, due to caste differences between the affected farmers, the MLA and the land brokers, the farmers again abandoned this strategy as they belonged to the most disenfranchised caste (Pillai) amongst the three groups.

One group of farmers whose lands had been taken enlisted the help of the Communist Party Marxist (CPM), the main party advocating for farmer rights, to get their lands back. The CPM confronted one of the land brokers and brought him to an affected village for questioning. The party also held a protest in the village in October 2007 to get the farmers' lands returned. In this instance involving five farmers, the tactics worked and the lands were returned.

Of the five other farmers whose lands had been taken without their knowledge or consent, three have filed court cases and two are still deciding what actions to take. Of the three court cases filed, one farmer has received his lands back. However, It took one year to receive the judgment and the farmer spent close to Rs. 12,000 in legal fees. While this particular farmer was reticent to comment on the toll of this occurrence, Visser and Spoor documented how similar scenarios compelled farmers to leave agriculture in Russia even though they received their lands back (Visser and Spoor 2011).

As result of the land acquisitions, many affected farmers and their family members have increased their time spent as laborers in nearby paper factories. The Sattur region has a long industrial history and was a main cotton trading hub in Colonial times (Baker 1984). Presently, Sattur taluk and neighboring Sivakasi taluk are two of the leading match, fireworks and printing centers for the country producing about 70% of the country's matches and 90% of the country's fireworks (Virudhunagar District Collector 2009). From 2008-2010, the only years for which data was available, the number of paper and printing factories in the region increased by 7% to 3,648 factories (Virudhunagar District Collector 2009; Virudhunagar District Collector 2010). Employment grew nearly 11% and at present, over 13,700 people are employed in the paper and printing industries in the region (Virudhunagar District Collector 2009; Virudhunagar District Collector 2010). While no data on wage trends was available, this increased proletarianization in Sattur, which mimics trends elsewhere through the state (Djurfeldt, Athreya et al. 2008), can have a downward pressure on wages by increasing labor supply, which will only be exacerbated if factories mechanize. Considering that the farmers in this study also lost their land, their ability to provision for themselves is uncertain as one of their main safety nets has been taken away.

Other farmers in the region, including one interviewed for this study, have become land brokers after the land acquisitions. Within the area, transitioning to wage labor is considered a demotion in social status. Migrating to the Middle East is a promotion in social status but this option is largely for younger men. Land brokering opportunities abounded given the increased demand for land and resultant increases in land prices.

Poothiraj was the main land broker facilitating the Shivaleekha acquisition. His elevation to land broker occurred because he spoke a few words of Hindi, the language spoken by company executives. He exchanged working in his fields for an air-conditioned office in Sattur. His entrepreneurial spirit helped him maintain the position, which he still holds while selling the remaining lands off into real estate. Numerous farmers spoke enviously of his good fortune and aspired to follow his path. One such farmer sold some of his land for the plantation and subsequently worked as a plantation guard for the company. He felt cheated by the sale because he sold four acres for Rs. 3,000 each and claims the price is now Rs. 240,000 each. He refused to sell his remaining eight acres to the company but he, like many other farmers I encountered in the region, has become a land broker hoping to benefit from the growing interest in land in the region and the subsequent increases in land prices. Irrespective of their motives for becoming land brokers, this growing class is helping the state achieve its wasteland development goals by perpetuating land acquisitions.

Land Prices

To examine how land prices have changed in the region since the land acquisitions began, the government guideline values for the surveys contained in the EC records were analyzed.

Guideline values are the state government valuations for each survey number. They are revised periodically to more accurately reflect market prices, typically after instances of increased land transactions.[81] Within Tamil Nadu, the guideline values were revised in August 2007, which coincides with the dates of the farmer land acquisitions in the plantation area. Thus, the guideline values for the surveys involved in the plantation were examined before and after the August 2007 revision to determine how land prices have changed in the region. Within Karsilpatti, Kongarakottai and Soorangudi, land prices increased an average of 43% per acre from an average of Rs. 9,615/acre in 2003 to Rs. 13,787/acre in 2007.[82] Karsilpatti experienced the largest land price increases of nearly 76% per acre, followed by Soorangudi (51%) and Kongarakottai (38%). Table 3.2 summarizes the changes in guideline values across the villages.

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[81] Interview with S. Anantharaja, Sattur document writer (25 January 2011).
[82] These prices are the 2010 inflation-adjusted prices.

Table 3.2: Land Price Changes in Plantation Villages

		Guideline Values[1]		
Village	**Records[2]**	**2003**	**2007**	**Percent Change**
	#	**(2010 Rs.)**	**(2010 Rs.)**	**%**
Karasilpatti	14	12,154	21,358	75.7%
Kongarakottai	129	8,969	12,357	37.8%
Soorangudi	8	15,603	23,607	51.3%
All villages	**151**	**9,616**	**13,787**	**43.4%**

Notes:

1. The guideline values presented in the table are the average 2010 inflation adjusted guideline values across surveys.
2. Guideline values were available for 151 out of 193 surveys in the EC records.

The changes in guideline values help substantiate the farmer accounts of significant land price escalation in the region, although the magnitude of the change in guideline values is less than the farmer accounts of market price changes. I was unable to obtain survey numbers for other villages in the region that were not part of the plantation. Thus, I am unable to determine the relation between land price increases in the plantation area and general land price trends in the area. However, the fact that the government reassessed land values in the state at the time of the plantation land acquisitions is a sign of increased land market activity in the state.

Discussion

This paper unveils the relationship between the Indian state and agrarian subjects in current land deal politics. If examined in isolation, the land acquisitions examined herein appear to be the result of poor biofuel policy making facilitated by local corruption. However, examining this acquisition in relation to the state's other land use policies reveals that the outcome in Sattur is not an unintended consequence of the state's biofuel policy. Rather, it is the direct result of the state's overarching land use priority of eliminating wastelands. In the eyes of the state, this occurs when such territories are put to more "productive" use through participation in one of the state's wasteland development projects. This has been an on-going project since Colonial times and continues to shape relations between state and subject to this day.

The Indian state defines what constitutes wasteland, designs wasteland classification procedures and enacts and funds wasteland development policies. Through these practices, the state set the conditions for a new class of land brokers to emerge who are helping carry out the government's program and improved their social status in the process. That the acquired lands in Sattur were not ultimately kept under biofuel cultivation is immaterial to the state. The lands are still being put to a more "productive" use by participating in the state's industrialization projects. The extent of wasteland has been reduced, at least on paper.

Although rural Tamil Nadu is in the process of industrializing, accelerating this process can increase inequalities for communities unprepared or unable to manage this transition without assistance. The state's construction of wastelands presents the territories as "empty", "unused" spaces available for development. This construction renders local users, and in this case, owners, invisible. Farmers whose lands were taken without their knowledge or consent received no help from the state to recover their lands and could not qualify for government drought assistance because they could no longer show title to their land. While some farmers in this case recovered their lands after political agitations or through court cases, some in this class have ended up abandoning their lands. Many farmers who have lost title have increased their work as wage laborers in nearby factories, increasing the politserization of the region. Further, that the plantation lands have been taken out of agriculture all together raises a host of questions that have yet to be answered about how these communities can provision for themselves going forward.

In the context of the land grab literature, this case contributes to a political sociology of the state (Introduction to this issue). It complicates portrayals of the state as weak and corrupt and for improved governance as a solution for curbing excessive land acquisitions (Arezki, Deininger et al. 2011). The Indian state facilitated the Sattur land acquisitions through its long-standing wasteland development program. The land use priorities and accompanying support mechanisms established under this program set the conditions for a new class of land brokers to emerge and execute the state's program. Further, on paper, India's governance of wastelands appears sound. Such lands are presented as empty, underperforming territories that can and should be put to a more productive state-defined use. However, when examined on the ground, the state's conceptualization of wasteland disappears as lands designated as wasteland are often in use and in this case, privately-owned. Thus, India's land use governance is a state-controlled project. Without analyzing the network of power relations shaping governance regimes and addressing what realities existing regimes obscure, calls to improve governance will do little to reduce land grabbing.

Theoretically, the Sattur land acquisitions are the product of governmentality. To achieve its goal of reducing wastelands, the state established numerous incentives to encourage subjects' participation in its project. Through the process of internalization, a class of land brokers emerged to carry out the state's project. Others whose lands have been acquired and have not become land brokers have found few outlets to contest the deals and are increasing their time as wage laborers. The ability of these subjects to provision for themselves is uncertain given the growing number of landless laborers pursuing similar strategies. Through this "wasteland governmentality", the state has shaped a class of land brokers and wage laborers through its wasteland development objectives. This conceptualization only becomes clear through a micro-level, qualitative analysis of state subject relations. Similar studies should be pursued to enrich our understanding of modern land deal politics and to develop more impactful remedies for curbing excessive land acquisitions.

Conclusion

Through an interdisciplinary investigation, this dissertation reveals the numerous fractures embedded in policy mandates calling for locating biofuel projects on marginal lands. Using evidence from India's National Biodiesel Policy, which restricts feedstock cultivation to "wastelands", I reveal how Prosopis juliflora biomass from India's wastelands currently supports a robust energy economy that services both rural and industrial consumers. Replacing this economy with Jatropha biodiesel could significantly reduce energy security and economic wellbeing because of low availability of biomass substitutes and possible job loss resulting from replacing biomass with biofuels. Further, the current biomass energy economy has a greater energy return on investment (EROI) (103) than Jatropha biodiesel (1.1-10.4) and provides 3.6 to 15.4 times more useful energy than a Jatropha economy.

In addition, India's promotion of wasteland-centered biofuel production has indirectly facilitated questionable land acquisitions of privately owned wastelands in southern Tamil Nadu. Instead of growing biofuels on the acquired lands, the lands are now being sold off into real estate. Dispossessed farmers are turning to wage labor in nearby factories or are becoming land brokers themselves, potentially fueling an intensifying cycle of dispossession. Such unanticipated outcomes occur because of the discursive power of the term wastelands, which, dating to the writings of John Locke, conjures images of empty, barren, unproductive territories utilized by similarly unproductive peoples. Framed in this manner, development policies since the Colonial era have targeted wastelands in order to improve the value of nature lying in waste and to craft moral citizens. Yet repeatedly, such schemes have offered little development benefits to the marginal and landless poor and have often resulted in land dispossessions and enclosures similar to what I have documented in the case of Jatropha promotion.

Policy Recommendations

As biofuels are likely to remain a fixture of future energy policy, especially due to the inclusion of the aviation industry in the European Union's Emission Trading Scheme (European Commission 2009), it is important to consider how, if at all, the findings of this dissertation can be translated back into policy. I offer three broad policy recommendations that will be elaborated in future work.

Contingency Provisions

First, to avoid unanticipated land deals such as the one documented in Chapter 3, it would be worthwhile to include contingency provisions in land transactions to better ensure lands are put to the use for which they were acquired (ie. cultivated with biofuel feedstocks). If lands are not used for these purposes, contingency provisions would allow the lands to be returned to the farmers or communities from which they were bought or leased. Further, such provisions could also apply in the case of project failures, which is always a possibility with the introduction of a new technology such as biofuels. Such contingency provisions could help reduce the amount of land speculation that has been cited as one of the main factors facilitating recent agricultural land acquisitions worldwide (World Bank 2010).

Further, contingency provisions could help reduce the information asymmetries that facilitated the land acquisitions documented in Tamil Nadu. Land brokers in collaboration with certain village level government officials helped operationalize the land acquisitions on behalf of the biofuel companies. Village officials were likely knowledgeable of the various government support programs in place to support biofuel production on wastelands and had access to and perhaps helped to generate land registration documents that identified wastelands. Land brokers were familiar with farmers in the region and perhaps knew whom to target for land acquisitions. Further, based on interviews with land brokers and government officials, the land deals documented herein do not appear to be a one-time occurrence in rural Tamil Nadu. Contingency provisions could help adjust these imbalances by giving additional power to local communities.

Yet, such provisions will require continued project monitoring in order to be effective. Various government officials interviewed for this study cited lack of funds for monitoring to explain why they did not know the current status of Jatropha trees planted within their territories. Biofuel certification schemes such as the Round Table on Sustainable Biofuels could adopt similar contingency provisions but will face similar needs to monitor projects.

Improved Land Assessment Procedures

Exploring the ability to improve land assessment procedures is another potential policy recommendation. However, this recommendation needs to be applied cautiously because of the multiple, potentially competing meanings of land to various stakeholders, which may be impossible to capture in a single assessment procedure. As an adapted cliché, one man's wasteland may be another's treasure.

As this dissertation demonstrates, current wasteland assessment procedures do not adequately capture the multiple dimensions that encompass the concept of marginal lands. These lands are simultaneously biophysical, economic, social and political spaces. Yet current assessment procedures prioritize the biophysical and economic dimensions. Social and political dimensions are admittedly more difficult to evaluate and may not be easily distilled into a land assessment partly due to their qualitative nature. Yet if current efforts to promote biofuels that minimize harm to communities and ecosystems are genuine, these dimensions must be acknowledged and given fair consideration in policy debates.

Similar to the contingency recommendation above, increased and improved monitoring may be one option for capturing the multiple dimensions of wastelands. Understanding how communities rely on marginal lands cannot be easily gleaned from remote sensing exercises or land registries as usage patterns may shift seasonally and may not be related to land ownership. Further, similar to the stakeholder perception analysis in Chapter 2, it is probable stakeholders maintain varying opinions on the significance of lands. These beliefs, if reflected in policy documents, may undermine government policy objectives. However, due to the repeated lackluster results of wasteland development policies, perhaps it is time for government and development agencies to change their discourse on marginal lands.

Land is now playing a dual role by supporting both food and energy production. This involves serious tradeoffs that are glossed over and obscured by current constructions of wastelands. By explicitly recognizing the multiple dimensions of lands and the limitations of current assessment procedures, policy makers can shift the debate from a question of wastelands to one of managing tradeoffs. This may be a more salient strategy for minimizing damages of development projects and for realizing marked improvements in energy and environmental security.

Looking Backwards and Horizontally

Lastly, policies should not be considered in isolation. They should be considered within a historic context as well as through a horizontal lens that simultaneously considers other policies related to the subject area. For example, India's biofuel policy should consider the outcomes of previous wasteland development schemes as well as current policies related to agriculture, rural development and climate change. Such an investigation would reveal the poor performance of past wasteland development schemes and would recognize how the same lands are now being targeted to meet India's energy, environmental and development goals.

More specifically, developing India's wastelands is not only contained in the National Biodiesel Policy but also the National Mission for a Green India, which has established a 10 mha afforestation target by 2020 (Government of India 2010). Further, within the course of my fieldwork, Tamil Nadu completed construction on a new highway that connects Madurai to the port of Tuticorin. Over the last four years, much of the land along the highway has been demarcated for real estate. It was therefore not surprising to learn that the lands acquired for biofuel production had been sold off into real estate because the blocks are only 2-3 km from the highway. Lastly, renewed interest in agricultural land in India has also been occurring globally as part of the so called global land grab debate (Cotula, Vermeulen et al. 2009; Von Braun and Meinzen-Dick 2009; World Bank 2010).

Such an evaluation may be a tall order for government as such considerations would require coordination across divisions and ministries. However, this may be an area for academics to better engage with policy.

While I realize the recommendations above may be a bit lofty, I would conclude that current biofuel policy making would benefit from improved consideration of possible unanticipated outcomes, increased project monitoring and evaluation and a more explicit consideration of tradeoffs involved with policy promotion. This hinges upon an assumption that governments want to improve policy outcomes and are committed to achieving thier stated policy goals. While some political ecologists question the motivations of government (Mosse 2004), based on my fieldwork, I believe that on the whole, government officials are committed to achieving positive outcomes that minimize harm to communities. Resource constraints certainly limit their abilities but this opens another avenue for academic contributions to policy processes given the duration and intensity of academic fieldwork.

Future Research Directions

For my future research, I would like to continue working on the social and environmental implications of changing land politics. As a first project, I plan to evaluate the role of agricultural financing in India's Jatropha promotion. I conducted close to 600 surveys with Jatropha farmers in southern Tamil Nadu and one of the main motivations stated for taking up Jatropha was the promise of a government loan. Through the survey data, I will investigate how agricultural financing in contributing to land use change in India.

Secondly, through my involvement with the Land Deals Politics Initiative (LDPI), I would like to expand upon the survey findings to examine the financial mechanisms facilitating global agricultural land investments. I suspect sovereign wealth and private capital investments may be a leading factor in land deals and I would like to examine how these investments are changing agrarian livelihoods. India plays a unique role in these investments as the country has been investing abroad, primarily in Africa, according to preliminary analyses (Von Braun and Meinzen-Dick 2009). I would like to examine the networks through which India is financing these investments and how such investments impact India's energy and food security. Emami Biotech's investments in Ethiopia may be a good starting point for this investigation (Goswami 2009).

Industrial ecology methods will also be useful for such an analysis as I could again draw upon sociometabolic theories to assess the energy and environmental implications of these investments. Further, as preliminary evidence of land investments suggest the land deals may be facilitating increased urban migration. Evaluating the environmental implications of urbanization is an emerging research topic in Industrial Ecology and drawing upon this knowledge may offer a unique perspective for conceptualizing the impacts of global land investments.

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