System Dynamics Modeling of Livelihoods and Forest Commons in Dryland Communities of Andhra Pradesh, India

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Abstract: The very poor, in drylands of India, survive because of vital ecosystem services from forest commons. Economic and environmental uncertainties, institutional variations governing ecosystems, and productivity of dryland cultivation intensify and complicate the linkages between household poverty and dryland forest commons. These economic ties to local ecosystems not only affect the biophysical properties of a forest commons but also how people organize their livelihoods at the household and community level that further influence local ecosystems. In this paper, we apply system dynamics modeling to examine forest ecosystems and livelihoods in a dryland village in Chittoor district of Andhra Pradesh, India. We do systems dynamic modeling with key stakeholders – the villagers, using traditional participatory action research techniques combined with group model building. This approach – Community Driven System Dynamics -- to derive data from actors to understand the structure of social-ecological systems and the behaviors they generate over time is innovative and holds significant value for understanding human and natural systems interactions. We present the results from a community driven system dynamics modeling research from a village in close proximity to a dry deciduous forest. Results include causal loop and stock flow models of feedback mechanisms between livelihoods, forests, and exogenous drivers mediating the social-ecological systems. Simultaneous examination of changes over time in both the management of forest commons and the diversified livelihoods of forest dependent rural poor in India 1) lends sharper insight into the linkages between social arrangements and forest ecosystems, and 2) identifies possible windows of intervention in human systems to affect forest extraction. In particular we test the effects of forest protection committees and the National Rural Employment Guarantee Scheme on livelihoods and forests.

Key words: System Dynamics; Social-Ecological Systems; Andhra Pradesh; Forests;

INTRODUCTION

The very poor, in drylands of India, survive because of vital ecosystem services from forest commons. The dynamic between household poverty and dryland forest ecosystems, is intensified by economic and environmental uncertainties, institutional variations governing ecosystems, and low productivity of dryland cultivation. Environmental uncertainties due to rainfall variation and frequent spells of drought make dryland agriculture risk prone. Risk and high variability in agricultural output push rural households to diversify their livelihood strategies beyond agriculture. Dependence on forest commons and other natural resources to supplement household subsistence needs and meet income shortfalls is ubiquitous. Local forest ecosystems meet both subsistence and supplementary income needs from a diverse range of products available in the forests – fuelwood for household and local commercial energy consumption, fruits and other products that supplement household dietary needs but also have local market value. Drivers of socioeconomic and ecological systems and feedback mechanisms between the two are multiple, difficult to generalize, and hard to reduce to a core representative set. Systematic study of social-ecological systems using new methods that enable subtle and nuanced understanding of the structures and multiplicity of drivers is critical for advancing an understanding of the dynamics between people and natural resources (Ostrom, Janssen, and Anderies, 2007). Only in knowing these complex drivers of livelihood mechanisms, that we might develop a nuanced understanding of the dependence of poor on forest resources and ways to intervene to achieve sustainable resource management and livelihoods. Renewed calls for studying social and ecological system inter-linkages are, however, unaddressed due to methodological constraints in capturing changing dynamics between social and natural resource systems. A significant concern in developing dynamic models of social-ecological systems is the source of data and the way it is generated, assuring a high level of confidence in the dynamic behavior.

In this paper, we describe the results from replication and simulation of fuelwood availability and extraction in Boyapalle community near Sadhukonda Forest Reserve in Chittoor District of Andhra Pradesh. The initial reference mode and the model structure producing fuelwood trends over time are replicated in this paper. We deploy a combination of participatory rural appraisal techniques with group model building to develop causal loop and stock-flow models of fuelwood availability and extraction from a forest adjacent to Boyapalle village. Our focus is limited to describing the replication and simulation of likely impacts on fuelwood availability and extraction from implementing two key policy interventions –community based conservation, and a rural employment guarantee intervention. We will elaborate on the drivers of fuelwood availability and extraction from the village forest area and forests beyond the village periphery. Our primary goal is to explain: 1) the feedback structure between livelihoods and fuelwood use, 2) from this structure of feedbacks, replicate dynamic problem of fuelwood availability over time in the forests near Boyapalle, and 3) test and simulate the likely impact on livelihoods and forest extraction from establishing forest protection and conservation rules and alternative employment opportunities through the National Rural Employment Guarantee Scheme.

We attempt to model social and behavioral drivers that underlie the use, protection, and regeneration of forest resource systems with the use of participatory rural appraisal (PRA) techniques and community driven group model building. Our aim is to understand the important pathways between forest ecosystems and survival of rural households and communities and how these critical linkages change over time. We utilize participatory methods to develop a model structure that explains fuelwood availability and extraction in Boyapalle forest over time. The essential nature of participatory appraisal technologies for systematic development of dynamic models of social-ecological systems (SES) becomes evident from our analysis. The use of participatory processes to build and verify underlying structures of feedback between community and forest ecosystems are discussed elsewhere in another paper (see Yadama, Hovmand, FES, Chalise, 2010).

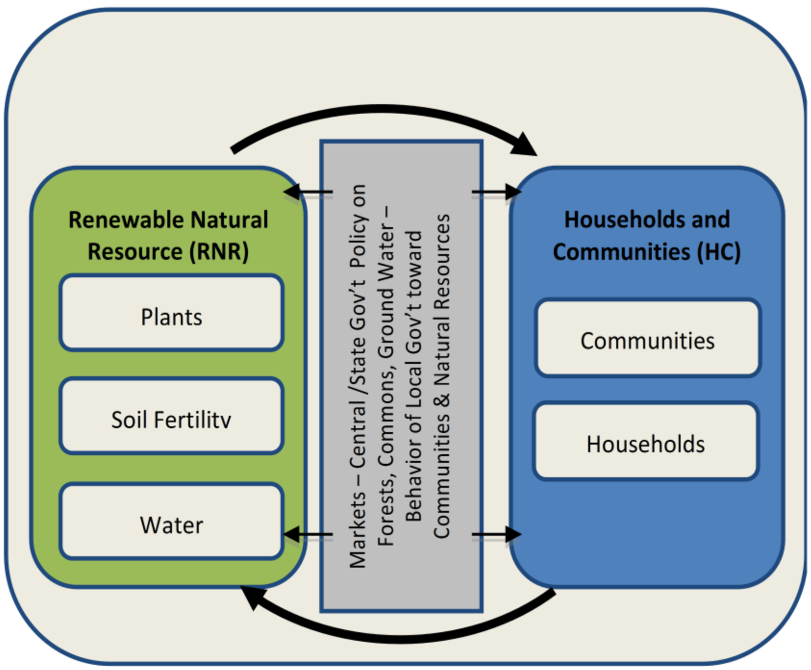
The analysis here is work in progress, and is undertaken in close collaboration with the villagers of Boyapalle village in Chittoor District of Andhra Pradesh, and the Papagni regional office of the Foundation for Ecological Security (FES), India. Key stakeholders are the Boyapalle community itself, FES staff working closely with the community, and professionals working with FES in the regional and central office of FES. Before involving the community, FES and the modeling team develop a common vision and goal for the modeling exercise with villagers. FES and the modeling team jointly approach a specific community and use participatory techniques to delineate a reference mode representing the dynamic problem, and a system dynamics model explaining the dynamic problem. In the next section we will review social-ecological systems and livelihoods of rural poor and the value added in thinking of SES as dynamical systems. We then show the use of community driven participatory techniques to model SES.

SOCIAL-ECOLOGICAL SYSTEMS: LINKAGES BETWEEN FOREST ECOSYSTEMS AND LIVELIHOODS

Forest commons play a central role in supplying the bioenergy needs of approximately 2 billion poor across the world. Rural poor depend on a variety of natural resources that are collectively managed and these include forests. Forests and other natural resource commons, support the energy demands of the poor from firewood, water demand for drinking and irrigation, and pasture for fodder for their animals (Inter Academy Council, 2007; Hegde et al., 1996; Godoy et al., 1995; Thomas-Slayter and Rocheleau, 1995). The use and governance of natural resources is complicated by the attributes of resources, communities and households, local government, nongovernmental actors, market and demographic influences, and by policies governing natural resources and rights accorded to communities (see Figure 1). Dynamics within the human social systems and among the multiple natural systems are complex and non-linear, and have numerous interacting feedback loops (Sterman, 2000). The condition and characteristics of natural resources influence individual and collective decisions of poor to protect, regenerate, and use resources. At the same time, collective and individual behavior of people has cumulative and unexpected effects on these vital natural resources.

There is, however, considerable ambiguity in our understanding of the underlying structures and mechanisms that drive human and natural systems interactions, including the dynamic interplay between local and national policy incentives, and the poverty of rural households and eventual sustainability of natural resource systems. While the state of knowledge around sustainable natural resource management superficially covers the ways communities depend on and manage natural resources, we have yet to capture nonlinearities, uncertainties, and dynamics that characterize human and natural system interactions (Agrawal, 2001; 2007; Agrawal and Chhatre, 2006; Matson, 2001; Ostrom, 2007). Simple assumptions of linearity, or more generally simplicity, in framing natural resource systems have led to low-leverage policies and panacea-like interventions that have little or no impact, fail to adequately address unintended consequences of interventions, or when successful, are difficult to transfer from one community to another (Forrester, 2007; Ostrom, 2007; Janssen, Anderies, and Ostrom, 2007). The case of Wolong Panda reserve in China highlights the low leverage and unintended consequences of conservation policies (Liu et al, 2007). Households inside the reserve were given subsidies ranging from 20-25% of income for monitoring harvesting. Original households in the reserve split into newer and smaller households to capture government subsidies, and in the process, the aggregate demand for fuelwood and land also grew putting further pressure on forests and the Panda population (Liu et al, 2007, 1515).

Figure 1: Overview of Natural Resource Systems and Household and Community Feedback Mechanisms



Whether induced by formal or informal institutional changes, how humans use natural resources has significant consequences for their condition. State subsidies for installation of borewells led to large scale shift by farmers to borewells for irrigation in Kolar district of Karnataka, India leading to a precipitous drop in regional water table (Cotton, 2006). Human interaction with natural resource systems and policies that induce behavioral responses significantly increase the number and type of feedback mechanism. The work of Ostrom has helped define social institutions as the key leverage point in the interaction between human and natural systems (Ostrom, 1990, 2001, 2007). Yet, there is far from consensus on which community institutional arrangements foster resource sustainability and how they can be applied from one context to another. For example, even when community self-governance becomes a sustainable solution, the question of scale often defeats system design and intent (Schuster, 2005). Scholars have called for new perspectives in understanding natural resource governance by poor communities wherein: data from disparate fields is synthesized; new data analysis techniques be developed to account for non-linearity; old assumptions of linearity are tested; broader inclusion of the realities and decision-making processes of individuals most affected; and greater collaboration among professionals from the social and natural sciences (Brock and Carpenter, 2007, cited in Ostrom, 2007, Koch et al, 2009; Daily et al, 2009). To move in this new direction, we combine system dynamics and participatory action research methods to build models of community and local forest interaction. We refer to this approach as Community Driven System Dynamics (CDSD). The goal is to understand how the mental models of different stakeholders: villagers, government officials, and NGOs shape their understanding of a natural resource, its trajectory, and their interaction and contribute to decisions about vital natural resources that are central to village livelihoods. We then leverage insights from data derived through participatory techniques into dynamic behavioral models to capture the complex interplay between socio-behavioral and natural resource systems. In this way, we answer the call for synthesizing data from disparate fields to model complex and non-linear social-ecological systems but in a deeply inclusionary way. Insights from participatory models from communities and households embedded in social dilemmas will help influence the design of program and policy interventions on behalf of the poor.

Community Driven System Dynamics is an iterative exercise that begins with a problem defined by the members of a community. To focus our modeling on a dynamic problem, we begin with a graph that traces a particular problem and the patterns of change over time. This graph or the reference mode becomes the point of reference for the modeling project (Ford, 2010, p. 13). In CDSD, we deploy participatory methodologies in a community to derive the reference mode, and continue with participatory methods to elicit explanations for the dynamic problem summarized in the reference mode. With the benefit of an agreed upon reference mode, the modeling process continues to the next step of building a basic stock-flow and a causal loop diagram. Subsequent steps involve estimating the parameter values, run the stock-flow model to replicate the reference mode, perform sensitivity analyses and examine the likely impact of policy and program interventions on the underlying structure explaining the dynamic behavior represented in the reference mode. We will first provide a background for the policies being tested in the model and describe our reference mode or the key behavior over time graph that is the focus of our model building. Then we will present an initial stock-flow and causal loop model of fuelwood availability in Boyapalle. Then we will illustrate the impact of key policy interventions on fuelwood extraction and availability.

PROGRAM INTERVENTIONS

Two significant policy innovations have implications for human and forest interaction. The first intervention is a village forest protection committee made possible under the Joint Forest Management policy implemented in India since 1990. The second more recent policy intervention is assured wage labor of 100 days guaranteed under the National Rural Employment

Guarantee Scheme of the Government of India (NREGS). The potential impact of NREGS on natural resource use remains unexamined and in this study we provide a first glimpse of its likely effects on forest use. Before elaborating on the different scenarios, we provide an explanation and motivation for examining the impact of these two policy interventions.

Forest Protection Committees (VSS)

A forest protection committee or a Vana Samrakshana Samithi (VSS) as it is referred to in Andhra Pradesh demarcates forest area that a community will be responsible for governing in collaboration with local forest functionaries within the framework of Joint Forest Management guidelines. As of 2006, more than 100,000 villages have formed forest protection committees to manage and conserve 22 million ha of forests across India. A set of common core principles guide these joint forest protection committees. Each forest protection committee is founded on rules to expressly manage and govern a demarcated area of forest in jointly with the local forest department. The idea is to involve and incentivize villages to take ownership and engage with local forest department functionaries as partners.[1] Once constituted and registered, a VSS is responsible for developing rules of management and protection that specifically govern the demarcated village forest. The operational rules and associated sanctions for violating the rules are clearly stipulated and agreed upon by the concerned community and the local forest department officials. Once a VSS is in place, communities, depending on the nature and structure of management arrangements, police the demarcated land, use, monitor, and sanction those that violate the use and conservation rules governing the designated forest. The ability of a community to engage key stakeholders, and impose new norms of forest governance is in many ways driven by norms of trust, reciprocity and reputational effect of members of the village (Agrawal et al., 2006; Agrawal & Yadama, 1997; Ostrom 1990, 2001). In addition, when village conflicts in general are fewer, the transaction costs of arriving at agreements vis-à-vis the VSS will also be lower. Other factors such as heterogeneity of a village, the frequency of interaction of villagers with forest officials, confidence in the local forest department to fulfill its obligations toward support and technical assistance to the VSS are all important in the sustainability of forest protection.

Boyapalle village VSS was established in 1998. Due to insufficient funds from the government, the forest protection committee became operational only in 2002. Nearly 233 hectares of the Sadhukonda Reserve Forest (SRF) located near the village are delineated under the protection of Boyapalle VSS. People from the village actively manage this area of forest by limiting extraction of fuelwood, constructing fire lines, and putting off fires. In Boyapalle, households distinguish two patches of forest, the village forest area designated within the VSS, and the reserve forest outside of the VSS boundary. In the Boyapalle model, we, therefore differentiate the

[1] Report National Committee on Forest Rights Act. Dec 2010. A Joint Committee of Ministry of Environment and Forests and Ministry of Tribal Affairs, Government of India. Dec 2010, pg. 21.

Sadhukonda forest into two different forest areas namely the Village Forest Area (VFA) and Outside the Village Forest Area (OVFA). VFA is proximate to the village and is the forest area being managed by the VSS since 2002. OVFA is that area which falls beyond the Boyapalle VSS, but an area of the forest from which Boyapalle households collect forest products including wood.

National Rural Employment Guarantee Scheme (NREGS)

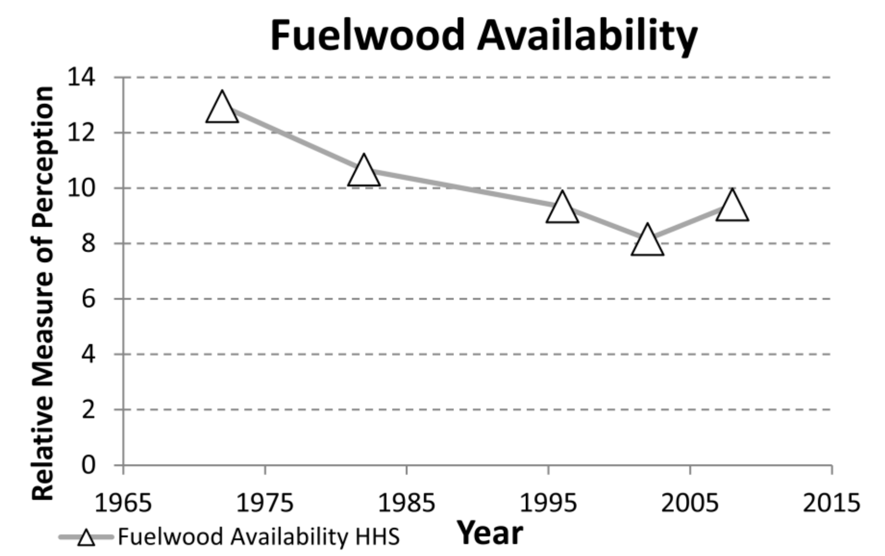
Rural employment generation policies will likely impact household income and potentially reduce dependence on forests for supplementary income. The National Rural Employment Guarantee Act of 2005 is a significant policy and program intervention to improve livelihoods in rural India. The National Rural Employment Guarantee Scheme (NREGS) provides, upon demand, opportunities for manual work within a 5 kilometer radius of a village. NREGS also stipulates that each household is eligible for 100 days of labor at a minimum wage of Rs 100 per day. Such a guarantee of labor for one adult per household is initiated upon demand by a household and the adult from that household will subsequently register to receive a job card. Once approved and issued a job card, an adult, by law is entitled for wage labor within 15 days of demanding work. Such a constitutional right to generate employment in the village is also available to a community or a village body that could plan the projects and make them available for people to earn an income. Villagers are given an opportunity to earn wages from among a platform of approved projects that focus on land development, soil and water conservation, and even afforestation. A third of the jobs, according to the NREGS must be allocated for women.

This combination of demand driven wage employment to people has significant implications for understanding the dependence of households and villages on local forests. Instead of earning a living selling fuelwood, it is very likely that households in a community could organize and demand wage labor. Subsequently, a Gram Sabah could put forth a plan for land, water, and soil conservation programs that ensure at least 100 days of wage labor annually for many of its adult members, and a third of them being women. An estimated USD 5.6 billion has already been expended in generating wage labor across rural India. Total investments will certainly increase with recent changes to NREGS; significant among these changes is a stipulation of Rs 100 as the standard minimum wage across India for anyone who works under the NREGS scheme. We wish to capture the potential impact of employment generation and the positive externalities on local forests from such alternative employment generated by NREGS. On the other hand, it is important to underscore that NREGS is not uniformly available in all villages. NREGS is more likely in communities where households demand wage labor, organize to work with local village bodies to develop programs for land and natural resource development, and in Panchayats that respond to such demand from its villages and households. For these reasons, we wish to model the drivers that make NREGS likely in a village, and also the downstream impacts of households earning wages through NREGS for at least 100 days annually.

REFERENCE MODE: Dynamic Problem of Fuelwood Availability

System dynamics models are built to represent the problem in a system and not the system itself (Sterman, 2000). Understanding and defining the problem is the first and most important step in the model building process. The dynamic problem is defined using a “Reference Mode”, which is a behavior over time graph representing the problem (see Figure 2). Fuelwood availability overtime is our reference mode for Boyapalle community. We derived this reference mode using a variety of methods including focus groups, participatory rural appraisal techniques, and a household survey. Our measure for fuelwood availability is a qualitative score based on the perception of community members. We used a relative measure for fuelwood availability due to lack of fuelwood data for the particular patch of forest in the forest reserve used by this particular community. While data were available for the entire Sadhukonda forest reserve, it was difficult to isolate fuelwood availability for a particular patch of forest in use by Boyapalle households. Therefore, we resorted to a relative measure, and multiple field methods to triangulate fuelwood availability over time for Boyapalle community. The reference mode suggests that overtime fuelwood has been in steady decline until 2002. Since 2002, there is an upward trend in availability of fuelwood, attributable to the establishment of a forest protection committee or Vana Samrakshana Samithi (VSS).

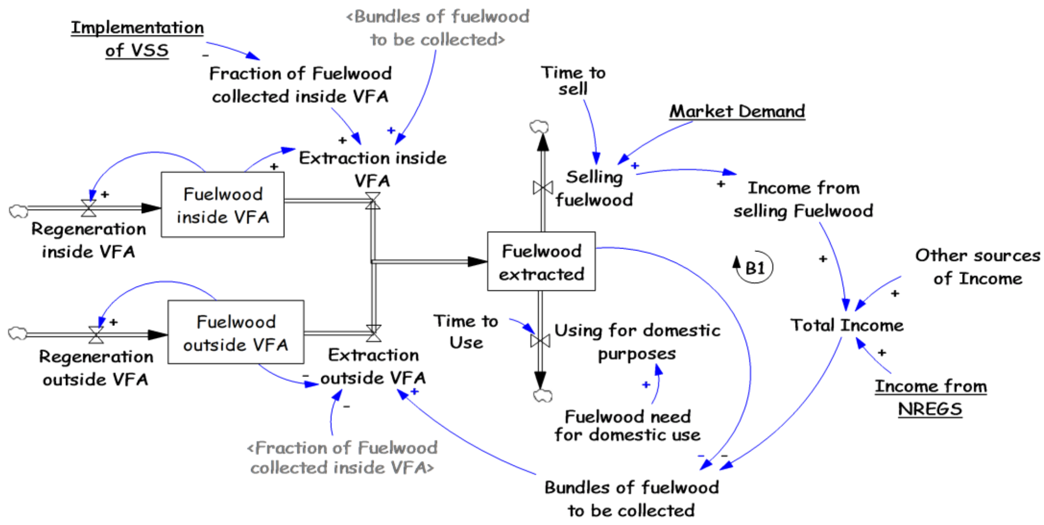
Figure 2: Reference mode of fuelwood availability



THE BOYAPALLE MODEL

Figure three, represents the simplified version of the model that was built based on the reference mode (see Yadama, Hovmand, FES, Chalise, 2010). The fuelwood available inside and outside the VFA are represented as two separate stocks that increase through regeneration of trees and decrease through the extraction of wood. Both stocks have a reinforcing loop with the regeneration inflow and balancing loops with the extraction outflow. The extraction outflows become the inflow for the stock fuelwood extracted, which represents the aggregate fuelwood extracted for different purposes. The stock of extracted fuelwood drains through two stocks:

Figure 3: Simplified version of the Boyapalle Model



selling fuelwood and using for domestic purposes. As the stock of fuelwood extracted goes down it increases bundles of fuelwood to be collected, which drives extraction. In the model, two main drivers of fuelwood extraction are domestic household needs and local market demand for fuelwood. Fuelwood extraction is also driven by total income because as income level decreases the villagers rely more on selling fuelwood however, there needs to be a demand for fuelwood in the market for them to be able to sell. Household use of wood is to meet energy demands of cooking, for fencing, and for agricultural implements. Market demand is cumulative of demand from hotels and households in a nearby town for cooking purposes and by brick-kilns in the area. Implementation of VSS decreases the fraction of fuelwood collected inside the VFA decreasing the extraction level inside the VFA. Participating in the NREGS program gives each household 100 days of employment per year. This increases the total income level reducing the reliance on fuelwood for income consequently decreasing the bundles of fuelwood to be collected.

SCENARIOS OF FUELWOOD AVAILABILITY AND PROGRAM INTERVENTIONS

Table 1: Matrix of different scenarios analyzed for fuelwood availability inside and outside Village Forest area

Scenarios	Forest Protection Committee (VSS)	National Rural Employment Guarantee (NREGS)	Local Market Demand for Fuelwood
Baseline	VSS Not Operational	No NREGS wages	Normal market demand for fuelwood
Scenario 1	VSS Operational	No NREGS wages	Normal market demand for fuelwood
Scenario 2	VSS Operational	All 64 households receiving NREGS wages	Normal market demand for fuelwood
Scenario 3	VSS Operational	All 64 households receiving NREGS wages	Increased market demand for fuelwood

We simulated multiple scenarios to examine the impact on fuelwood availability both inside and outside the village forest area adjacent to Boyapalle village (VFA). See Table 1, for an overview of the mix of program interventions and level of market demand for fuelwood in the baseline and each of the three alternative scenarios (see table 1).

VSS Influence: Scenarios inside the Village Forest area (VFA)

In our simulation, we introduce a VSS in 2002, compare scenarios of fuelwood availability and extraction with, and without the presence of VSS (see scenario 1). In our model, VSS reduces the level of extraction of fuelwood and damage caused by fire. Similar to the reference mode the simulated behavior also shows a decline of fuelwood availability over time, and an upward trend after the VSS is established in 2002. In figure 4, Run 2, labeled "without VSS+NREGS 0" indicates a declining trend for availability of fuelwood in the absence of VSS. The first run (Run 1) represents a scenario in the presence of VSS.[2] It is evident that fuelwood availability varies in the presence of a forest protection committee; trending down in the absence of a VSS and improving and becoming stable in the presence of VSS. The subsequent two graphs

Figure 4: Fuelwood Availability inside the Village Forest Area (VFA)

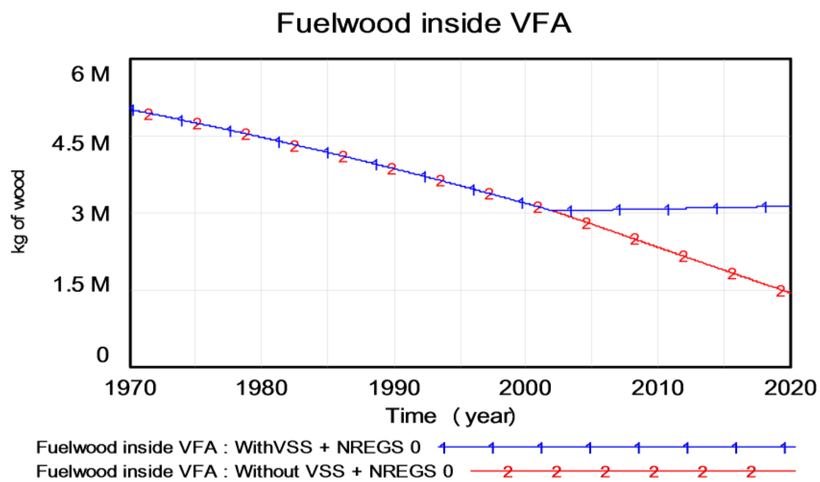
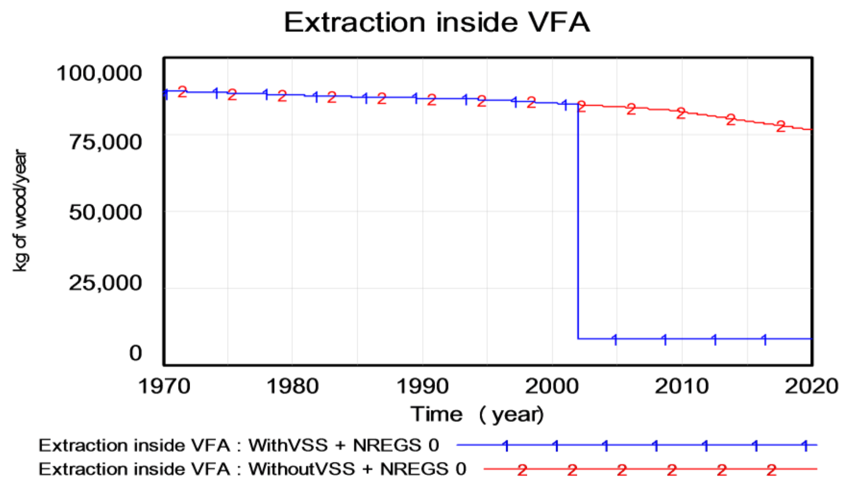


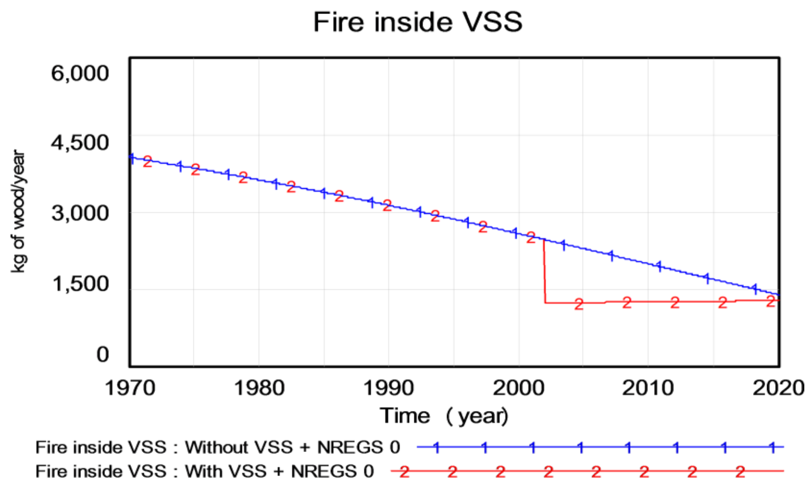
Figure 5: Fuelwood Extraction inside Village Forest Area (VFA)



[2] NREGS stands for "National Rural Employment Guarantee Scheme" and fuelwood available inside VSS is the stock of fuelwood available, measured in Kg of wood, inside the Van Samrakshana Samithee (Forest protection Committee).

(Figures 5 and 6) elaborate on the differences in fuelwood extraction from forest areas under the VSS and those outside the institutional arrangements governing the management of forest. Constraints on fuelwood extraction by VSS result in a sharp decline in fuelwood collected inside VFA (as shown in Figure 5). Prior to the operation of a VSS, our model assumes equal extraction from all areas of the forest. Post VSS, only five percent of the fuelwood is extracted from inside the VFA. This is derived from monthly Boyapalle household data collected in the field from October 2009 including levels of wood extraction. Data show that each household in Boyapalle collected one bundle per week for selling, which amounts to 3072 bundles per year with reported weight of 27 kilograms per bundle. Each household collected 1.26 bundles per week for domestic use, amounting to 3900 bundles per year with a reported weight of 22 kilograms per bundle. Establishment of the VSS also organized the community members to address forest fire resulting in less damage (See figure 6). In all these runs, the number of households in Boyapalle receiving income through the National Rural Employment Guarantee Scheme (NREGS) is maintained at zero that is none of the households are participating in NREGS. This replicates the scenario on the ground where households from Boyapalle are not receiving any employment through NREGS programs.

Figure 6: Loss of Fuelwood by Fire inside Village Forest Area (VFA)



VSS Influence: Scenarios outside the Village Forest Area (VFA)

While extraction of fuelwood within the VFA is reduced, the overall demand for fuelwood remains the same. The policy works only to restrict extraction of fuelwood from a certain area but not to reduce the actual demand of fuelwood. Since people still need fuelwood for various domestic purposes and as an income source, they go outside the village forest area to fulfill their need. In other words, the burden of fulfilling the demand shifts beyond the protected area as an unintended consequence of the VSS policy. With this shift, the trend for availability of fuelwood outside the VSS worsens (Figure 7, Run 1) because of the increase in extraction in this part of the forest (Figure 8, Run 2). The field data suggests that the patch of forest outside the village forest area is fulfilling almost 95% of the demand.

Figure 7: Fuelwood availability outside the Village Forest Area (VFA)

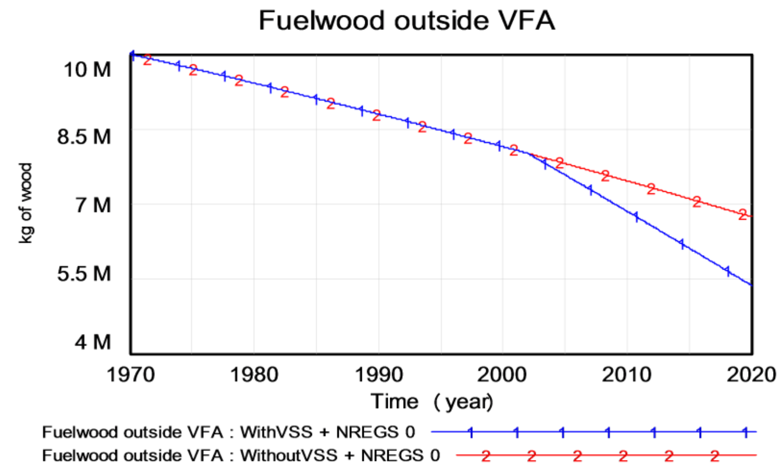
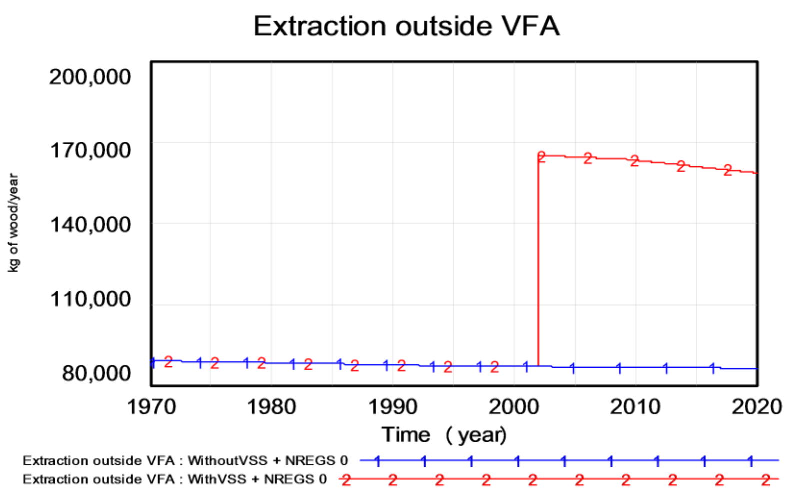


Figure 8: Extraction outside the Village Forest Area (VFA)

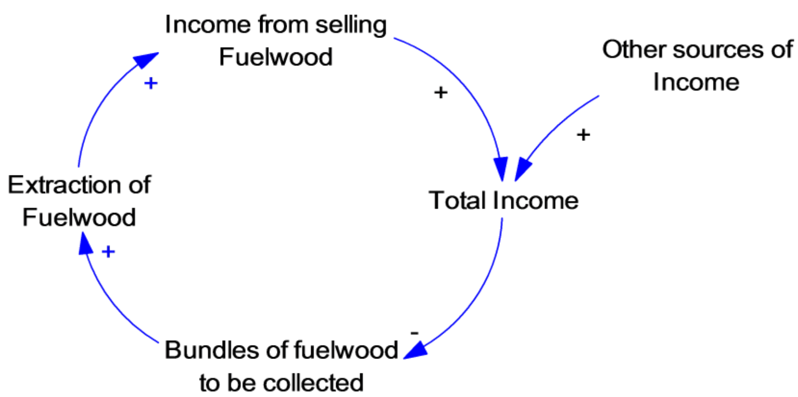


NREGS Influence: Scenarios inside the Village Forest Area (VFA)

An important feedback loop in the model concerns income and its link to extraction of fuelwood (Figure 9). Fuelwood extraction for selling in local markets for supplementary income is an important livelihood strategy in Boyapalle. From our modeling exercises, the people of Boyapalle, however, have a clear preference for wage labor over fuelwood extraction to earn an income. However, wage labor does not produce sufficient income and people rely on fuelwood to supplement income. The dynamic between income and extraction of fuelwood is negative. As households extract more fuelwood to sell, it increases their income and through increases in extraction of fuelwood and fuelwood sold, we increase the total income such that as the total income increases the need for extraction decreases, thereby balancing the process. When people earn an income from other sources such as the National Rural Employment Guarantee Scheme (NREGS), their total income increases, and as a result, overtime fuelwood extraction decreases.

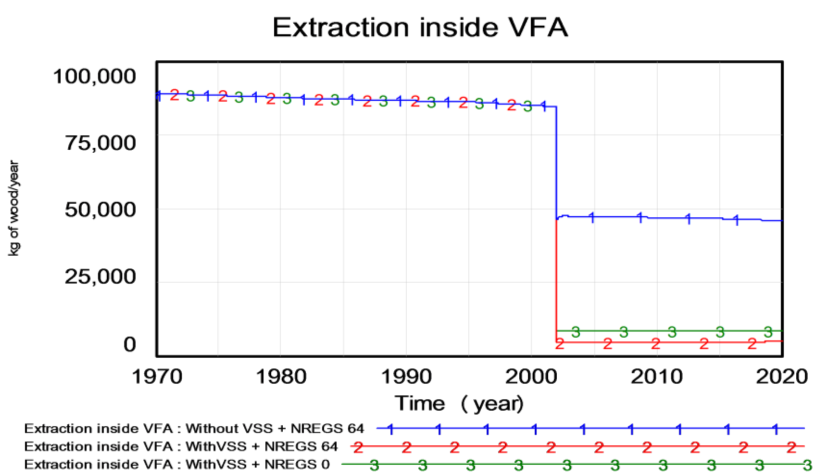
Using this feedback loop structure, we ran some simulations where all 64 households were earning wages from NREGS and compared it with conditions where none of the households are earning NREGS wages.

Figure 9: Feedback loop between income and extraction



In our baseline and first scenario, we assume that zero households are receiving income through NREGS. Our assumption is consistent with conditions on the ground in Boyapalle.[3] Inside the VFA, we do not see a significant difference in fuelwood extraction when we change the conditions from none of the households receiving wages from NREGS to all 64 households having income through NREGS (Figure 10a, Run 2 and 3). The explanation is simple: fuelwood extraction is already curtailed and regulated within the boundaries of the VSS, and therefore any incremental reductions in extraction due to increases in wage labor inside the VSS protected forest are small. Our simulations indicate that NREGS could reduce fuelwood extraction by almost half, but not as much compared to the reductions from establishing a VSS as shown in previous simulations (Run 1). One of the benefits of system dynamics modeling is the ability to modulate the time horizon of the model and observe longer-term impacts. In figure

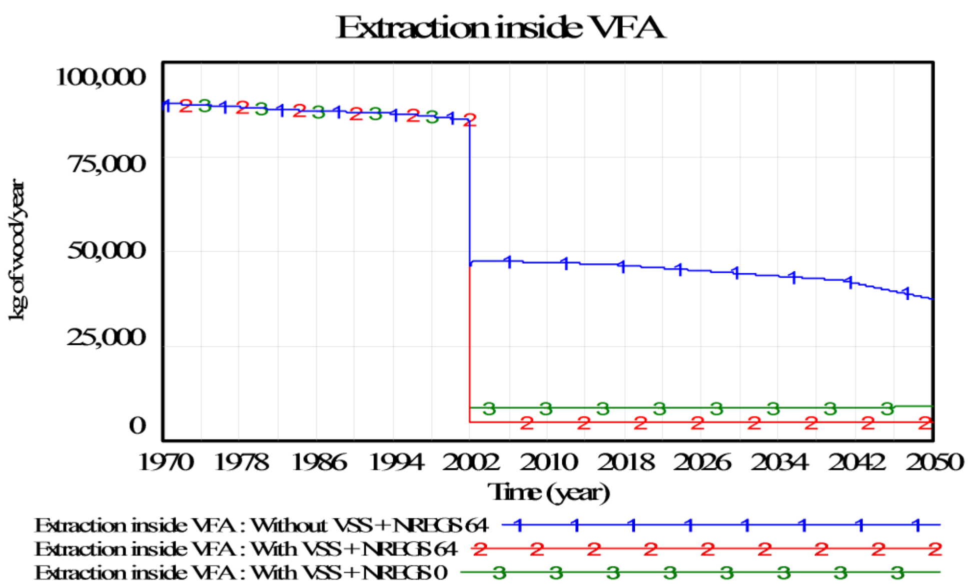
Figure 10a: Extraction of fuelwood inside the Village Forest Area (VFA)



[3] Monthly data collected from October 2009 till August 2010 shows that only in the months of May, June, and August did 2, 3, and 5 households received work under NREGS.

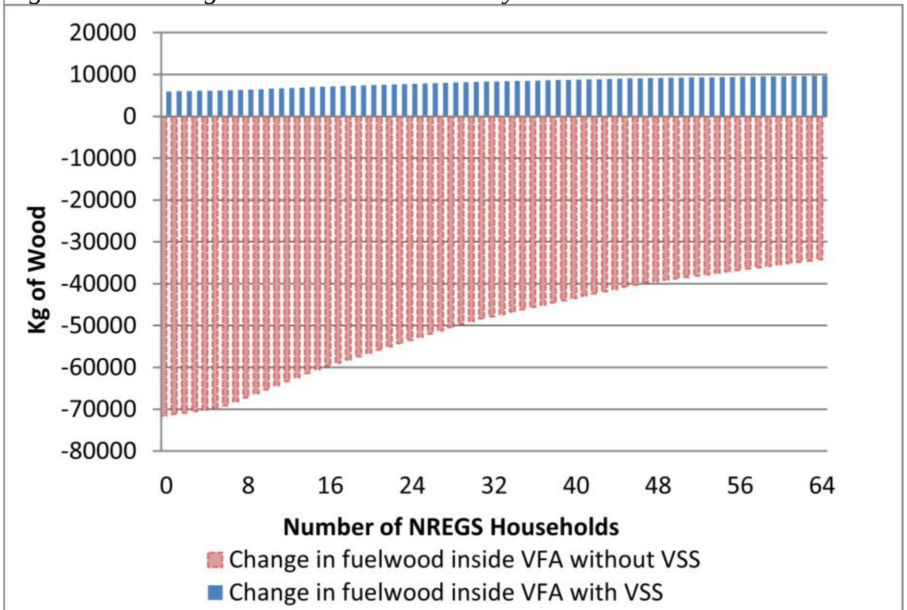
10b, we extend the time horizon to 2050 for fuelwood extraction. After 2020, in a scenario where there is no VSS but all 64 households obtain wages from NREGS, the extraction of fuelwood begins to decline. This is not because demand for fuelwood has decreased but because the total availability of the fuelwood in the forest begins decreasing, making it difficult for people to extract more.

Figure 10b: Extraction of fuelwood inside the Village Forest Area (VFA) until 2050



In figure 10c, we examine the effect of earned wages through NREGS on changes in fuelwood availability inside the village forest area. The simulated data from a year after the two interventions (VSS and NREGS) was used to produce the graph. The change in fuelwood availability represents the difference in the stock of fuelwood between the years 2002 and 2003. There are two different scenarios: with and without VSS. The change in amount of wood inside the village forest area (kg of wood) is represented on the y-axis

Figure 10c: Change in Fuelwood Availability between 2002 and 2003 inside VFA



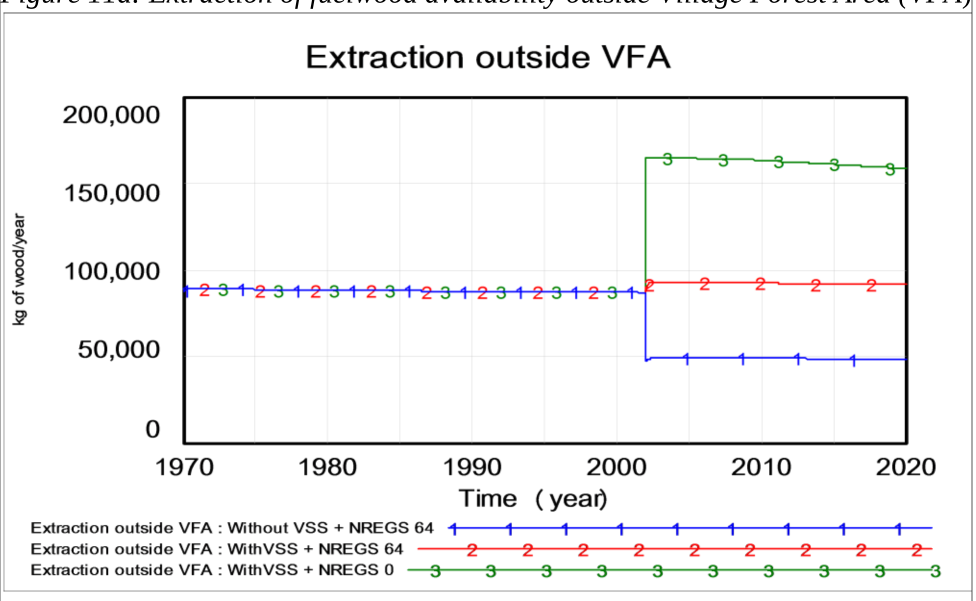
and the number of households participating in NREGS is indicated on the x-axis. In the scenario where the local institutional arrangements to protect the forest are absent (without VSS), fuelwood availability is on a decline (change in fuelwood availability is always negative) however, the rate of decline slows down as more households begin to participate. When none of the households participate in NREGS, the fuelwood scenario is the worst. As more households participate in NREGS and have alternative sources of income, change in fuelwood availability improves and the effect begins to taper as the final few households also begin to earn through the NREGS program. This suggests that even in the absence of local institutional arrangements the rate of forest loss can be stemmed with increasing number of households earning income by participating in the NREGS program. Even though fuelwood availability never increases, the impact of NREGS on slowing down the rate of decline could be significant.

In the scenario where the local institutional arrangements to protect the forest are in place (with VSS), the fuelwood availability increases (change in fuelwood availability is positive). The rate at which the change in availability of fuelwood is increasing, improves as more households begin to participate in NREGS. The rate of change in this case is not as steep as the one without VSS because when the institutional arrangements are in place the level of extraction is already minimal. This leaves marginal room for improvement by further reducing extraction.

NREGS Influence: Scenarios outside the Village Forest Area (VFA)

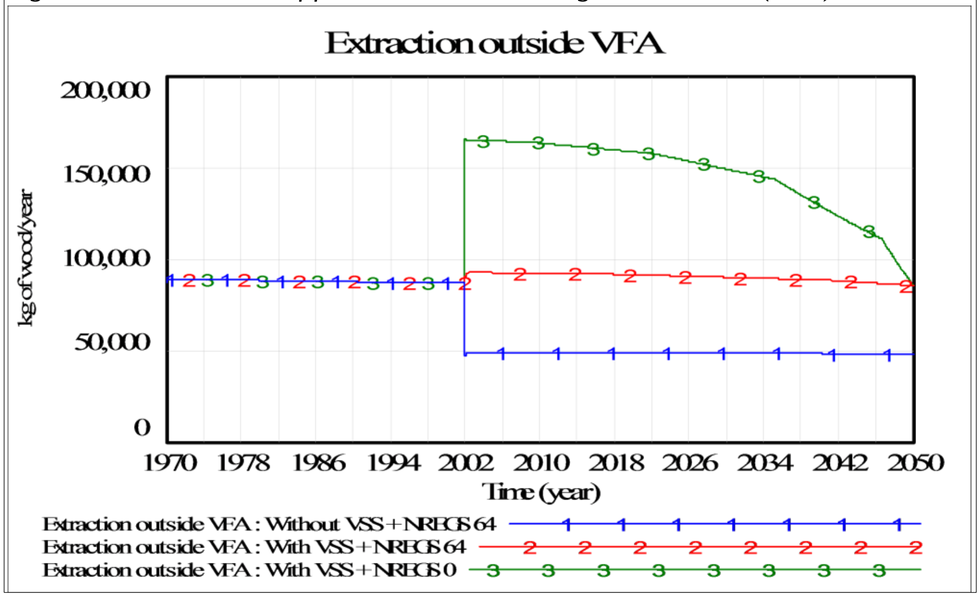
In our simulations when none of the households are participating in NREGS and a VSS is already established, we see a jump in fuelwood extraction outside the VFA (Figure 11a, Run3). However, when all 64 households receive wages through NREGS, and a VSS is established, the level of fuelwood extraction outside the village forest area drops significantly (Run 2). As peoples wages from NREGS increase, they no longer supplement income from selling fuelwood, and our simulation indicates a drop in fuelwood extraction from forests both within

Figure 11a: Extraction of fuelwood availability outside Village Forest Area (VFA)



and outside the village forest area. In the presence of a VSS, we surmise that any extraction in fuelwood from outside the village forest area is for household purposes. In the final simulation, we test the likely outcomes in the absence of VSS, but all the households earn additional income through NREGS projects (Run 1). There is a further drop in the level of fuelwood extraction from areas outside the village area because fuelwood extraction is more evenly distributed among the different patches of the forest. While VSS reduces levels of extraction inside the VFA, it increases the extraction outside the VFA. NREGS intervention, on the other hand, decreases extraction throughout the forest – both inside the village forest area and outside the village in the general forest. Unlike VSS, NREGS addresses the root cause of extraction in Boyapalle, i.e. lack of stable income. NREGS wages address the problem of shifting extraction from a managed and governed forest area to an unprotected area as in the case with only VSS intervention.

Figure 11b: Extraction of fuelwood outside Village Forest Area (VFA) until 2050

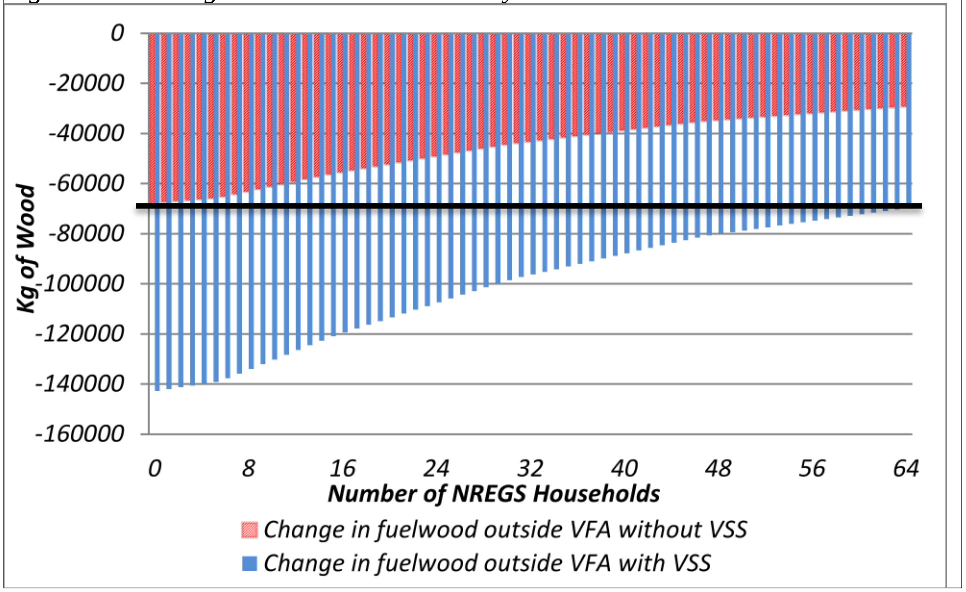


We simulate fuelwood extraction outside village forest area into year 2050 (Figure 11b). In an extended time horizon, we observe an initial spike then a drastic drop in extraction of fuelwood outside the VFA, when a VSS in operation and none of the households receive wages from NREGS. The burden of extraction of fuelwood shifts outside the VFA when VSS becomes operational and as extraction continues, fuelwood stock depletes over time, making it harder for people to extract beyond a certain point, and this is the likely explanation for drop in extractions over time when a VSS is implemented in Boyapalle. By 2050, the extraction level is similar to the scenario as if all the households are getting wages through NREGS and a VSS is operational. The pattern of behavior, however, is not one of sustainable extraction but reduced extraction through reduced availability.

In figure 11c, we examine the effect of earned wages through NREGS on the changes in fuelwood availability outside the village forest area. There are two different scenarios: with and without VSS. The change in amount of wood outside the village forest area (kg of wood) is represented on the y-axis and the number of households participating in NREGS is indicated on the x-axis. In both the scenarios, (with and without VSS), the fuelwood availability does not increase however; the rate of decline of fuelwood availability slows down as more households begin to participate.

In both cases, the change in fuelwood availability is worst when none of the households participate in NREGS. Although the two cases have similar attributes, the scenario with the local institutional arrangements differs in two ways. First, the magnitude of amount of change in fuelwood is much higher and secondly, the impact of more households participating in NREGS on change in fuelwood availability is more significant. As discussed earlier, when the VSS is implemented the burden of fulfilling the fuelwood demand shifts mostly to outside village forest area. This results in more extraction in this part of the forest, which explains the higher level of change in fuelwood. Consequently, since there is more extraction, there is more opportunity for reduction in extraction with income earned by participating in NREGS. For example, if 100 kgs of wood is being extracted from part A and 10 kgs is being extracted from part B, a 50% reduction in both would yield a reduction by 50 kgs in part A and only 5 kgs in part B.

Figure 11c: Change in Fuelwood Availability between 2002 and 2003 outside VFA



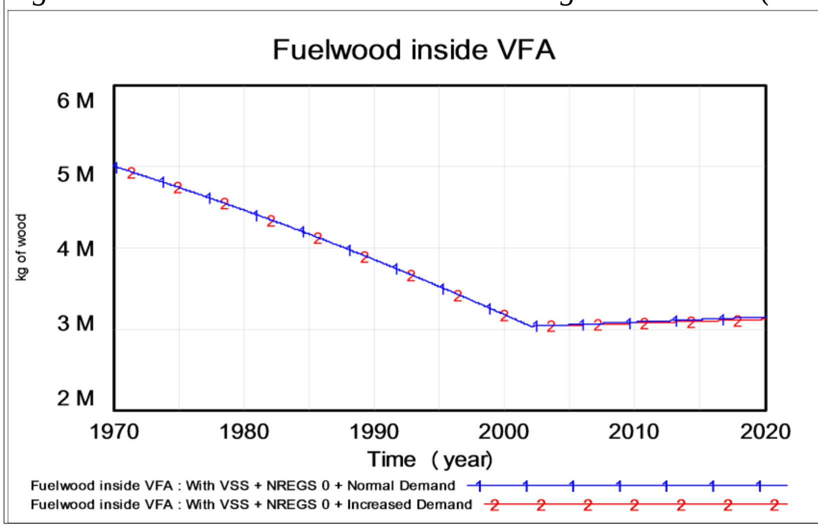
It can be observed in the figure that the change in fuelwood with VSS and all of the households participating in NREGS is similar to without VSS and none of the households participating in NREGS (see horizontal line in middle of the figure). Households participating in NREGS help to counter the unintended increase in demand outside the village forest area caused by the establishment of VSS inside the village forest area. This suggests that the implementation of policies to protect the forest should happen in tandem with policies that can reduce the actual demand of fuelwood, such as NREGS, to ensure that unprotected parts of the forest are not overexploited.

LOCAL MARKET DEMAND FOR FUELWOOD

Market demand for fuelwood is generated from the food vendors and the households living in the small towns within a 10km radius of Boyapalle village. The food vendors are either small hotels or street food vendors who serve the people coming in the town. Households living in these towns rely on fuelwood sold by villagers for their daily cooking and heating needs. Solid biomass remains the dominant choice of fuel for both of them. Demand for fuelwood spikes during the election season as the food vendors have to serve people coming from out of town and during festivals as the households prepare meals for their friends and family. In all previous simulation runs, local market demand from nearby small towns has been kept constant but in this scenario the market demand is doubled. We simulate the impact of increased market demand for fuelwood on availability both inside and outside the VFA.

Market Demand: Scenarios inside the Village Forest Area (VFA)

Figure 12: Fuelwood available inside Village Forest Area (VFA)



In our model, we double the market demand in 2002 to understand the impact of fluctuations in market demand. In an earlier figure, we find that there is minimal impact on fuelwood extraction inside the VFA when none of the households are receiving NREGS wages, but VSS is in effect (Figure 12). Similarly, high market demand for fuelwood does not produce change in fuelwood availability inside the VFA because only 5% of the fuelwood demand is met from here (Compare Run 1 and 2). This suggests that the VSS acts as a buffer against fluctuations in market demand.

Market Demand: Scenarios outside the Village Forest Area (VFA)

We have already seen that establishment of VSS results in greater extraction of fuelwood in areas outside the VFA (Figure 7). Now when there is increased market demand the trend of fuelwood available outside VFA worsens because of the pressures to meet the increased demand in fuelwood. This is represented in figure 13, where Run 2 represents the scenario with increased demand. What would be the outcome, however, if all the households earned income through NREGS? When market demand is increased, fuelwood availability trends down (Run 1), but when all 64 households receive NREGS wages, the downward trend is on a much slower decline (see figure 14, Run, 2). Even when demand increases, the presence of NREGS is able to buffer the impact of increase in market demands. In comparing Run 2 and 3, we notice that the trend for availability of fuelwood is better for increased demand when households have income through NREGS, than in times of normal demand and without any of the households receiving income through NREGS. Steady income from non-forest related activities is critical for protecting the forest from increases in market demand for fuelwood. An interesting point to note in the graphs for fuelwood availability outside the VFA is the downward trend over time, even when all households have income through NREGS. Households, typically extract fuelwood for two purposes, selling and domestic use. When people have additional income through NREGS the amount of fuelwood sold for income will reduce, but it will not have any impact on the fuelwood collected for domestic use. In the long-run, given the current regeneration rates of forest, without reductions in the amount for fuelwood collected for domestic use, it may be very difficult to improve the condition of the forest outside the VFA.

Figure 13: Fuelwood Available outside Village Forest Area (VFA)

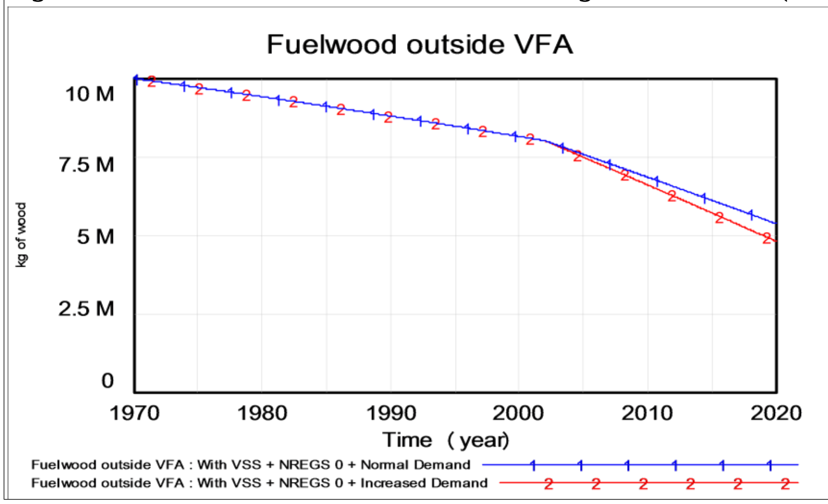
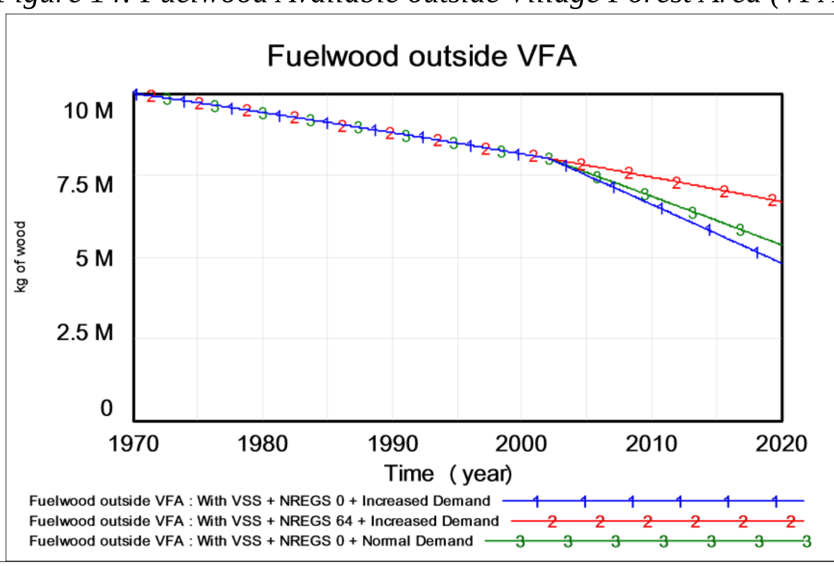


Figure 14: Fuelwood Available outside Village Forest Area (VFA)



CONCLUSION

Through the various simulation runs, we might conclude that local institutional arrangement such as Forest Protection Committees (VSS) do work to improve the conditions of degrading forest ecosystems however; they do not address the root causes of the problem. If people's need for forest products such as fuelwood is not met from one part of the forest, governed through local institutional arrangements, people will just shift the burden to the next patch of forest that does not have such governance structure or lacks an enforcement mechanism. In such cases, other parts of forest could face increased degradation as an unintended consequence of the VSS policy. For the community members of Boyapalle, a significant reason for extracting fuelwood was to supplement their income. In the model, the forests are in better state when households are able to participate in NREGS and earn an extra income. Both the local institutional arrangements to protect the forest and households participating in NREGS seemed to buffer the increased demand for fuelwood from the market. This suggests that provided people have supplementary income and there are institutional arrangements in place, the shocks from the market will not have any profound impact on the health of the forest. The best-case scenario in the model is when the VSS is implemented because this is the only scenario when the availability of fuelwood started to increase. Forests did much better when all of the households were participating in NREGS however; even with both the policies, the trend for availability of forest outside the VFA never becomes positive. This is mainly because the domestic need for fuelwood contributes equally to extraction and the supplementary income from NREGS is reducing the need to sell the fuelwood but not the domestic need. It is clear that institutional arrangement to govern the forest commons, policies to provide employment, and interventions to help households reduce their domestic need of fuelwood should work in tandem to improve the condition of the forest.

In this model, the VSS policy is a constant however; in reality, the local institutional arrangements and the level of enforcement are dynamic. Whether people follow rules or not could depend on myriad of endogenous factors such as shared norms regarding extraction and exogenous factors such as environmental risks. The next logical step for the research is to expand the model to incorporate the endogeneity of the local institutional arrangements to get at the nuanced understanding of the interactions between social and ecological interactions.

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