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

Nishesh Chalise[1], Gautam N. Yadama[1], Peter Hovmand[1], and

Foundation for Ecological Security (Papagni Cell, Andhra Pradesh)

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 discuss system dynamics and it use and value in examining the interplay between forest ecosystems and livelihood strategies 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 will present the results from a community based system dynamics modeling research from a village in close proximity to a dry deciduous forest. Results will 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 biophysical aspects of forest commons and the diversified livelihoods of forest dependent rural poor in India will 1) lend sharper insight into the linkages between human and forest ecosystems, and 2) point to high leverage points of intervention in such coupled social-ecological systems.

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

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[1] George Warren Brown School of Social Work, Washington University of St. Louis, One Brookings Drive campus Box # 1196, St. Louis, MO, 63130, USA. Correspondence to nchalise@wustl.edu or yadama@wustl.edu

INTRODUCTION

The very poor, in drylands of India, survive because of vital ecosystem services from forest commons. The dynamic between household poverty and commons such as dryland forest ecosystems, is intensified by economic and environmental uncertainties, institutional variations governing ecosystems, and lack of productivity in dryland cultivation. Environmental uncertainties from variations in rainfall and frequent spells of drought make dryland agriculture more risk prone. Risk and high variability in agricultural output push rural households to diversify their livelihood strategies beyond agriculture to dependence on natural resources that supplement household subsistence needs and meet income shortfalls. Local forest ecosystems meet both subsistence and supplementary income needs because of the diverse nature of products that are available in the forests – fuelwood to address household energy needs and fuel shortfalls in nearby regional markets, fruits and other products that supplement household dietary needs but also have a 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 the inter-linkages between social and ecological systems are, however, unaddressed due to methodological constraints in capturing 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 derived which assures 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 deployed a combination of participatory rural appraisal techniques with group model building to develop a causal loop and a stock-flow model of fuelwood availability and extraction from the forest adjacent to Boyapalle village. Our focus in this paper is limited to describing the replication and simulation and the 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 in the village forest area and forests beyond the village periphery. Our primary goal is to describe: 1) the linkages between livelihoods and fuelwood use, 2) replicate the reference mode of fuelwood availability over time in the forests near Boyapalle, and 3) simulate the likely impact of establishing forest protection and conservation rules and alternative employment opportunities through the National Rural Employment Guarantee Scheme.

With the help of participatory rural appraisal (PRA) techniques and community driven group model building, we attempt to model social and behavioral drivers that underlie the use, protection, and regeneration of forest resource systems. A central focus of our community embedded modeling is to understand the importance of forest ecosystems and their linkages with survival of rural households and communities and the changing nature of these critical linkages over time. In this study, we utilize participatory methods to develop a model structure that explains fuelwood availability and extraction in Boyapalle over time. The critical nature of participatory appraisal technologies for systematic development of dynamic models of social-ecological systems becomes evident from our analysis. Participatory processes through which we establish and verify underlying structures of community and forest ecosystems interaction and feedback have been discussed elsewhere in another paper (see Yadama, Hovmand, FES, Chalise, 2010).

The analysis presented 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 individual households, 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, it is critical that FES and the modeling team join in a common vision and goal for the modeling exercise with villagers. Only then, FES and modeling team jointly approach a specific community and use other participatory techniques to delineate a reference mode, and a system dynamic model. The next section of the paper will provide the social-ecological systems and their importance for the livelihood of rural poor. With that context, we will explain our approach to understanding and modeling such systems, and advantages of using participatory and community driven techniques to elicit a system dynamic model.

SOCIAL-ECOLOGICAL SYSTEMS: LINKAGES BETWEEN FOREST ECOSYSTEMS AND LIVELIHOODS

Forest commons play a central role in supplying the energy 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 demands of the poor for energy from firewood, water for drinking and irrigation, and pastures for fodder for their animals (Inter Academy Council, 2007; Hegde et al., 1996; Godoy et al., 1995; Thomas-Slayter and Rocheleau, 1995). We propose to advance our understanding of the complex interactions between poor households and communities and the array of natural resources that are essential for their survival. How do - interactions between natural resource systems and uncertainties affect the ability of poor communities to address governance challenges – protect, regenerate, and use vital natural resources – over time? Our study examines how impoverished rural communities govern vital forest resources under varying resource system complexities, and other uncertainties including market and environmental (see Figure 1).

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. Therefore, the dynamics within the human social systems and the multiple natural systems, as well as the relationships across them are complex and non-linear, and have multiple 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.

How rural communities protect, manage, and use a community forest will determine not only the condition of that forest, but also other natural resources closely linked to that forest – such as ground water availability in nearby villages, or soil fertility in adjacent agricultural lands. In Kenya, highland farmers are known to intensely cultivate cropland that in a previous generation was forested land. As soils degrade and fertility is lost, there is further conversion of forests into agricultural lands leading to food insecurity over time and across generations (Liu et al, 2007). Declining forests or conversion to other uses often produces the strongest adverse effects for the poor (Agrawal, Chattre, and Hardin, 2008; Agarwal, 1994; Yadama et al., 1997). Complexity, therefore, is not only in people and natural resources interactions, but also in how changes in one category of resources leads to condition and availability of other resources vital for people's livelihoods. Yet another complication in these interactions stems from differing perspectives within communities on the utility, use, and governance of resources. Complexity escalates when vital resources – forests or ground water – are targets of state policy intervention. Governments influence community and household incentives to protect, regenerate, and use vital natural resources such as forests, water, or soil. These incentives could be positive or perverse in their impact on natural resources. The Chinese conservation policy's impact on curbing illegal harvesting in Wolong Panda reserve is illustrative of non-linear and surprise effects (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).

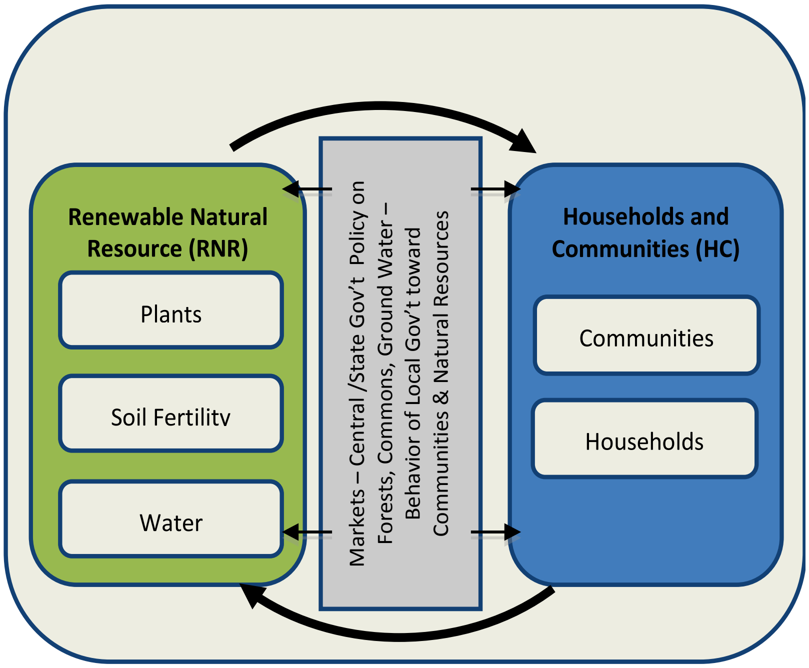
There is, however, considerable ambiguity in our understanding of the underlying structures and mechanisms that drive human and natural systems interactions, including the dynamic interplay between local and national policy incentives, and the poverty of rural households and eventual sustainability of natural resource systems. While the state of knowledge around sustainable natural resource management superficially covers the ways communities depend on and manage natural resources, it has not captured the nonlinearities, uncertainties, and dynamics that characterize human and natural system interactions (Agrawal, 2001; 2007; Agrawal and Chhatre, 2006; Matson, 2001; Ostrom, 2007). False assumptions of linearity, or more generally simplicity, in 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).

The vast literature on the commons, even as it identifies common pool resources (CPRs) managed by communities as a complex coupled human and natural system, has failed to accurately capture their complexity and nonlinearity in space and time (Koch et al, 2009, 36). New dynamic models must address factors that gain greater salience over time, and how others become irrelevant. Dynamic complexity exists not only within resource systems but also between them. The majority of studies of natural resources and common pool resources have focused on a single resource, such as forests (Tucker, Randolph, and Castellanos, 2007; Gibson, Williams, and Ostrom, 2005; Agrawal and Chhatre, 2006; Varughese and Ostrom, 2001), water (Bardhan, 2000; Meinzen-Dick, 2007), or fisheries (Njaya, 2007). Yet diverse natural resources are coupled and their condition is mutually interdependent (McGrath, Almeida, and Merry, 2007). Approximately 4.6 billion people depend on forests for water (Millennium Ecosystem Assessment, 2005). There is emerging research that recognizes ecological interdependence of CPRs and that users of one CPR, say water, have a stake in the governance of other critical CPRs such as forests (Sarker, Ross, and Shrestha, 2008). Natural resources are socio-ecologically interdependent as ecological and social processes intersect.

Whether induced by formal or informal institutional changes, how humans use natural resources yields significant consequences for their condition. FES conducted a preliminary analysis of forms of irrigation – water tanks, open dug wells, and bore wells – and their impact on water table in Kolar district of Karnataka. Data indicate a significant shift in mode of irrigation by poor farmers to bore wells because of state government subsidies for installation of such wells, and groundwater mapping analysis implicates state subsidies and a precipitous drop in regional water table (Cotton, 2006). Similarly, there is a high correlation between increasing irrigation-based agriculture and decreasing water table levels on the High Plains of Kansas (Kettle, Harrington, and Harrington, 2007).

The addition of human interactions and activities to natural systems increases the number and type of feedback mechanisms. There is still ongoing discussion on what types of relationships and feedback actually generate sustainable usage and stewardship across different circumstances and arrangements. 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 how community institutional arrangements can foster resource sustainability and how they can be translated 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). In collaboration with the Foundation for Ecological Security (FES), a nongovernmental organization (NGO) working with rural communities in the state of Andhra Pradesh, India, we carried out system dynamics modeling using participatory methods. We refer to this approach as Community Driven System Dynamics (CDSD). The goals is to understand how different groups of villagers, government officials, and NGO members contribute to decision making by these communities about vital natural resources

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



central to their livelihoods. We then incorporate 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. Models built on the basis of participatory data from communities and households embedded in social dilemmas are bound to lead to influencing program and policy interventions on behalf of the poor.

We will first describe our reference mode or the key behavior over time graph that is the focus of our model building.

REFERENCE MODE

System dynamics models are built to represent the problem in a system and not the system itself. Understanding and defining the problem is the first and most important step in the model building process. In system dynamics language, problem definition is to establish a "Reference Mode" (Sterman , 2000). Fuelwood availability overtime is our reference mode for Boyapalle community. In the community of Boyapalle, we developed a 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 was 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 had to use 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 till 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).

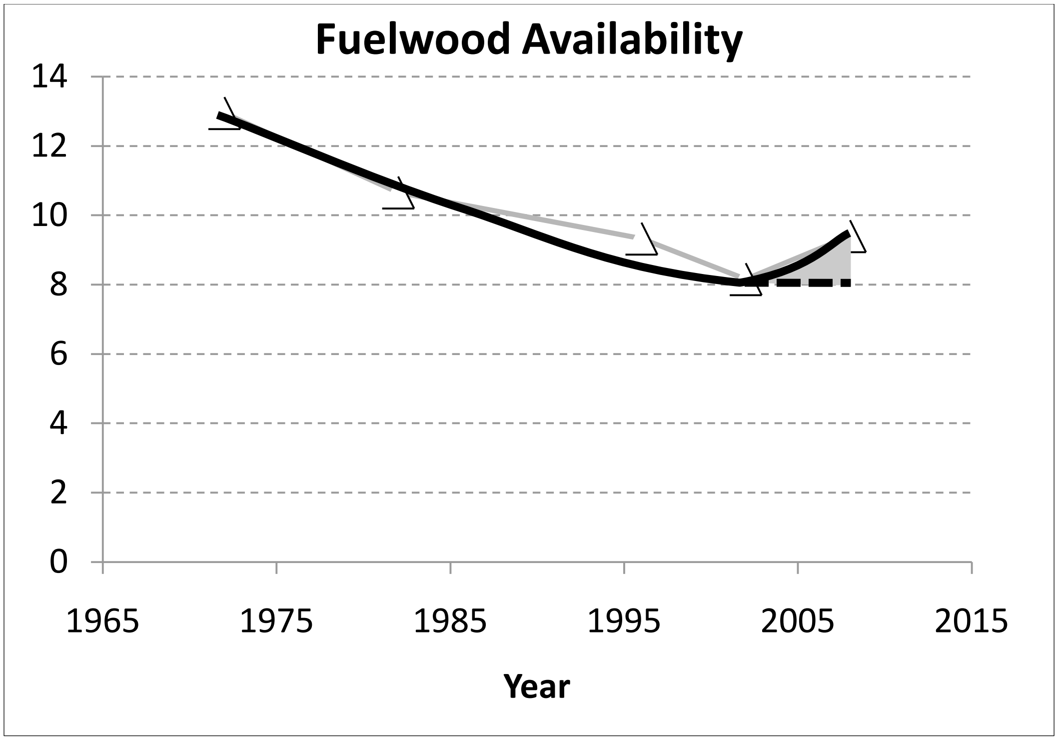


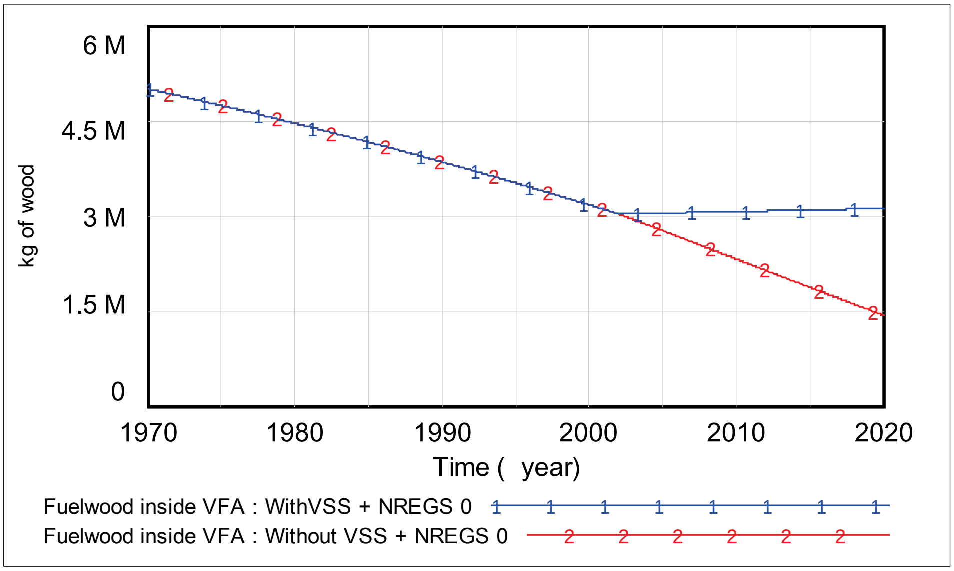
Figure 2: Reference mode of Fuelwood Availability

ESTABLISHMENT OF VSS (FOREST PROTECTION COMMITTEE)

Boyapalle village VSS was established in 1998 but due to insufficient funds from the government, the operations started only in 2002. Nearly 233 hectares of the Sadhukonda Reserve Forest (SRF) located near the village is delineated under the protection of Boyapalle VSS. People from the village began actively managing 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 forest area into two different forest areas namely the Village Forest Area (VFA) and Outside the Village Forest Area (OVFA). VFA is close to the village and is the same piece of forest area designated as the VSS in 2002. Outside VFA is an area that falls beyond the Boyapalle VSS where Boyapalle households go to collect fuelwood.

Scenarios inside the Village Forest area (VFA)

Figure 3: Fuelwood Availability inside the Village Forest Area (VFA)



In our model, we introduce VSS in 2002 and compare scenarios of fuelwood availability and extraction with and without the presence of VSS. When VSS is established, it 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 3, the run labeled “without VSS+NREGS 0[2]” (Run 2) shows the trend for availability of fuelwood in the absence of VSS. The other run (Run 1) shows the scenario in the presence of VSS. It is evident that fuelwood availability varies in the presence of a forest protection committee. The subsequent two graphs (Figures 3 and 4) elaborate on the differences in fuelwood extraction from village forests area under the VSS and forest area that falls outside the institutional arrangements governing the management of forest. Constraints in fuelwood extraction from village forest area imposed with the establishment of VSS results in a sharp decline in fuelwood collected inside VFA (as shown in Figure 4). Before the VSS was established, there were no demarcations of protected area so the model assumes that there is equal extraction from both areas. However, after VSS only 5 percent of the fuelwood is extracted from inside the VFA. This value was calculated from the household data collected in the field from October 2009 along with the levels of extraction. Data shows 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. For domestic use, each household collected 1.26 bundles per week, which amounts to 3900 bundles per year with 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

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[2] NREGS stands for “National Rural Employment Guarantee Scheme” and fuelwood available inside VSS is the stock of fuelwood available inside the Van Samrachyan Samitee (Forest protection Committee) which is measure in Kg of wood.

figure 5). Forest fires are associated with “high temperatures that penetrate the soil, influence forests and their ability to regenerate by altering the soil properties, killing soil microbes, plant roots, and seeds; destroying soil organic matter, and altering soil nutrient cycling” (Frandsen and Ryan, 1986, p. 246). In all these runs, the number of households in Boyapalle receiving income through the National Rural Employment Guarantee Scheme (NREGS) is maintained at zero, which is none of the households is being employed through NREGS projects. This replicates the scenario on the ground where households from Boyapalle are not receiving any employment through this policy.

Figure 4: Fuelwood Extraction inside Village Forest Area (VFA)

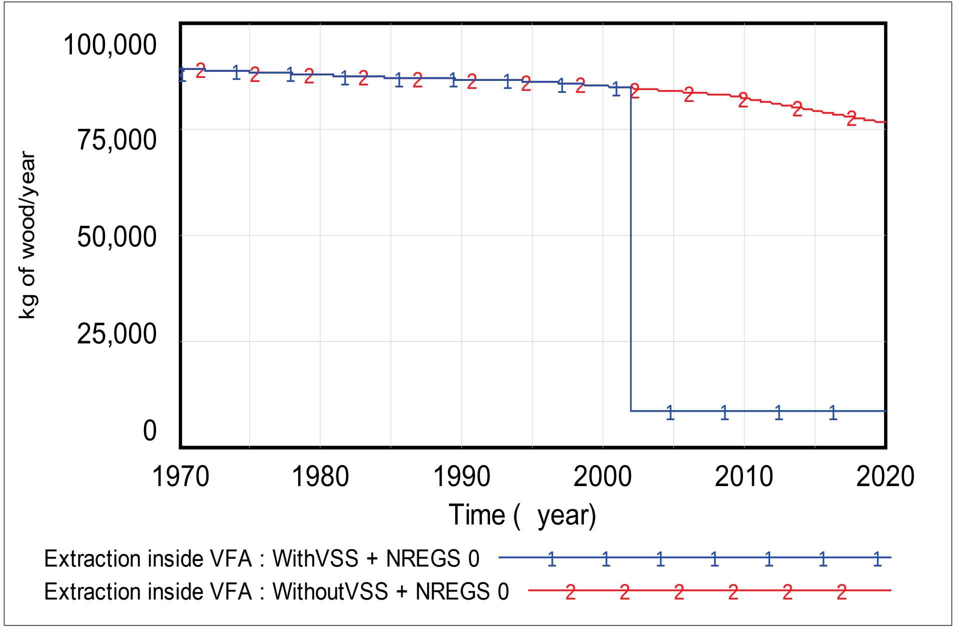
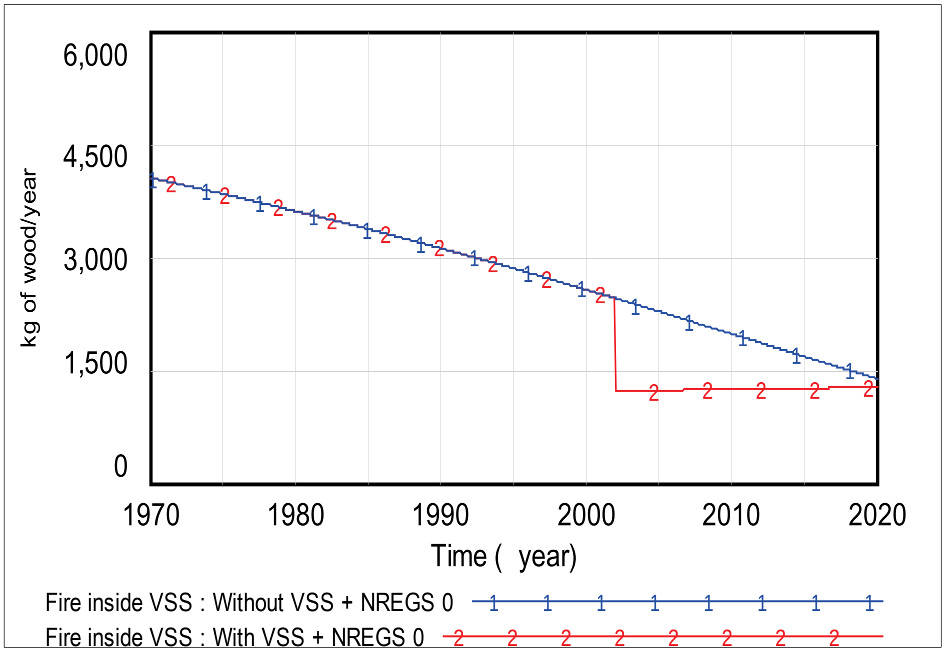


Figure 5: Loss of Fuelwood by Fire inside Village Forest Area (VFA)



Scenarios outside the Village Forest Area (VFA)

With the establishment of VSS, people reduce extraction of fuelwood inside the VFA. Their demand for fuelwood, however, does not reduce. This demand is fulfilled by extracting wood from outside the VFA. With increased extraction, the trend for availability of fuelwood outside the VSS looks worse than before (Figure 6, Run 1). Before the VSS, we assume that the larger forest is meeting half the demand (i.e. the level of extraction was equal) of fuelwood, but after the establishing a VSS, almost 95 percent of the demand is being met from outside village forest area. In figure 7, we can see the drastic increase in extraction (Run2) levels after the implementation of VSS.

Figure 6: Fuelwood availability outside the Village Forest Area (VFA)

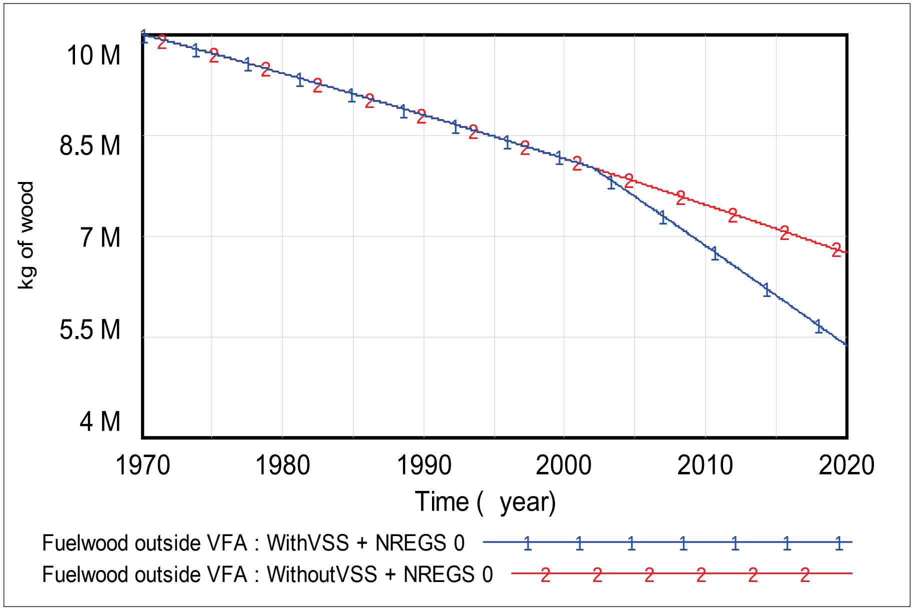
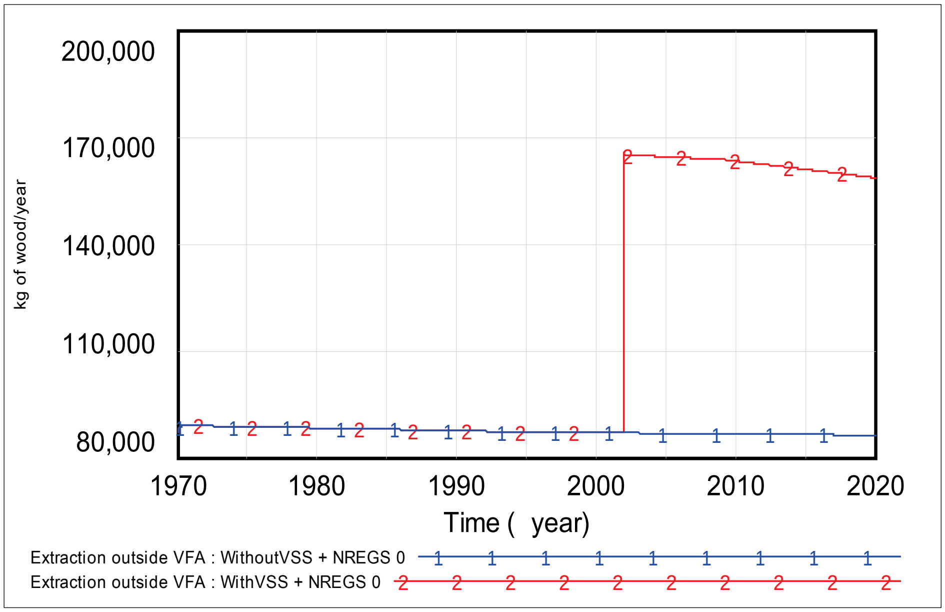


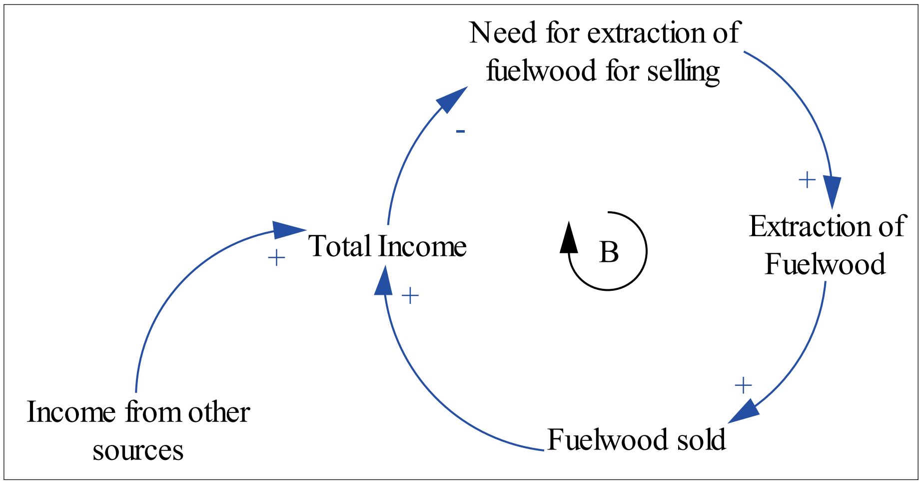
Figure 7: Extraction outside the Village Forest Area (VFA)



INTRODUCING NREGS

One of the important feedback loops in the model concerns income and the linkages to extraction of fuelwood. Extraction of fuelwood to sell in local markets for supplementary income is an important livelihood strategy. The people of Boyapalle have indicated a clear preference for wage labor to fuelwood extraction. However, wage labor does not produce sufficient income and people have to collect fuelwood to meet their needs. In figure 8, the linkage between income and need for 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. In system dynamics, this is a "balancing loop" because as the total income increases the need for extraction decreases, thereby balancing the process. When people earn income from other sources such as through National Rural Employment Guarantee Scheme (NREGS), their total income increases, and thereby overtime decreases fuelwood extraction. Based upon this feedback loop structure, ran some simulations where all the 64 households were earning money from NREGS and compared it with where none of the households were earning money from NREGS.

Figure 8: Feedback loop between income and extraction



Scenarios inside the Village Forest Area (VFA)

Until now, we had zero households receiving income through NREGS in the model, which is also the case in the field[3]. Inside the VFA, we cannot see a very big difference between none of the household having income and the entire households having income through NREGS (Figure 9a, Run 2 and 3). This is because when VSS is established, the amount of extraction inside the forest regulated by the VSS is already controlled which reduces the effect of increased income. If we want to see the impact NREGS has in the absence of a VSS, then we can do that by not introducing VSS in

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[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.

2002 but introduce NREGS for all the households. Our simulations indicates that NREGS would reduce the extraction by almost half but not as much compared to the reductions from the establishment of VSS as shown in previous simulations (Run 1). One of the benefits of system dynamics modeling is also the ability to change the time horizon of the model. It is possible to increase the time horizon to observe the long-term impacts. In figure 9b, we can see that the time horizon is increased to 2050. After 2020, in a scenario where there is no VSS and none of the households obtain work from NREGS, the extraction of fuelwood begins to decrease. This is because the total availability of the fuelwood in the forest starts to decrease making it harder for people to extract more.

Figure 9a: Extraction of fuelwood inside the Village Forest Area (VFA)

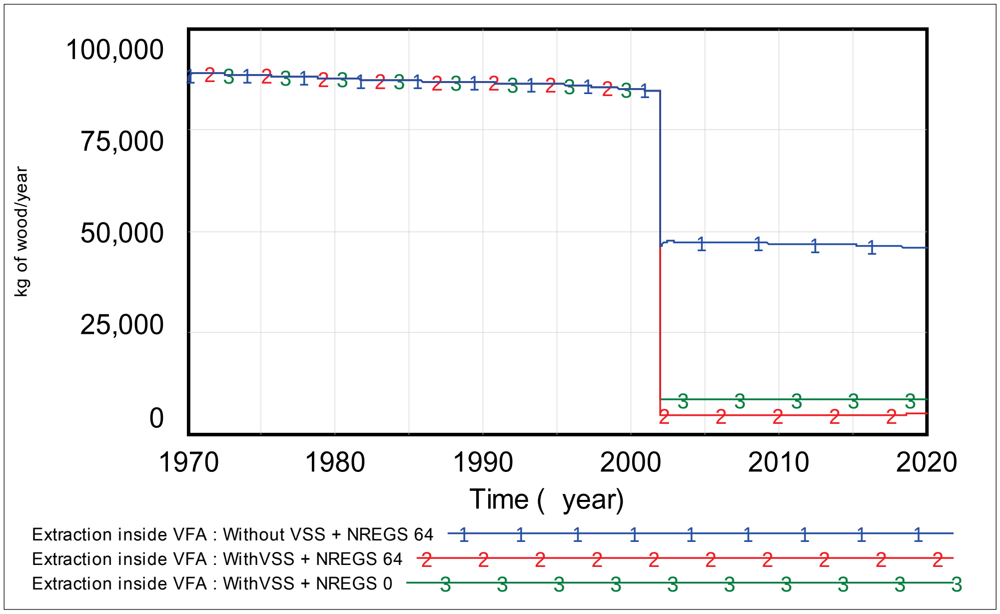


Figure 9b: Extraction of fuelwood inside the Village Forest Area (VFA) until 2050

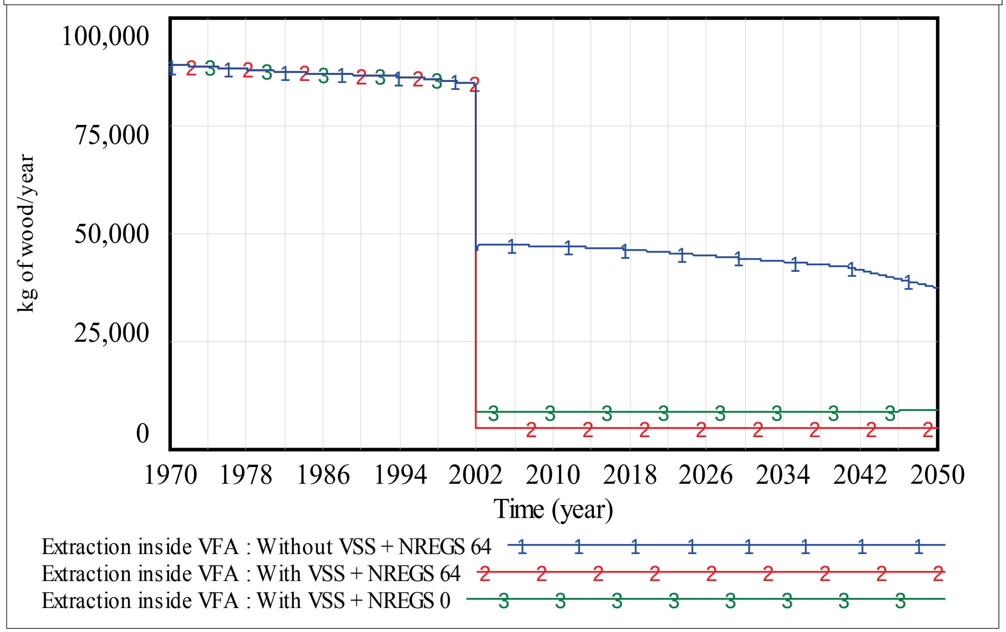
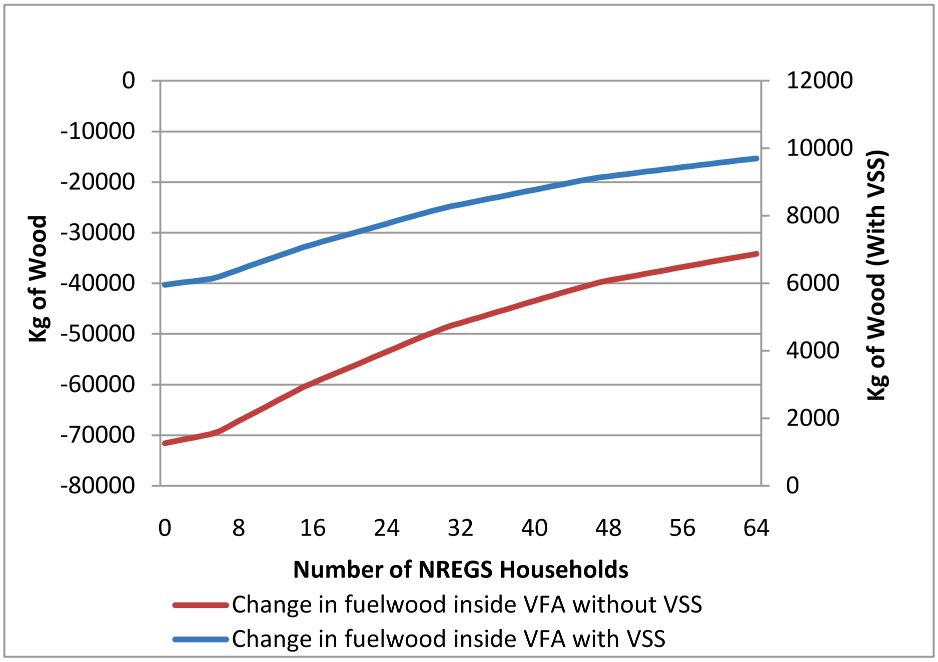


Figure 9c: Change in Fuelwood Availability between 2002 and 2003 inside VFA



Further analysis reveals the impact on the change in amount of fuelwood available, as the number of households participating in NREGS increases. As more households earn income from NREGS projects, the change in availability of fuelwood between 2002 and 2003 improves (Fig. 9c). When VSS is implemented (Y-axis on the right side) the change in availability of fuelwood improves from 5953 kilograms of wood to nearly 9702 kilograms. When VSS is not present the change in fuelwood availability is negative (see Y- axis on the left side) but improves from around negative 71,579 kg of wood to negative 34,158 kg of wood when number of households participating in NREGS increases from zero to 64, which is the maximum number of households in the village. In the scenario, where VSS is operational (3748 KG of wood) the improvement is less significant than when VSS is not implemented (37421 KG of wood). This is easily explained; when VSS is implemented the extraction is already minimal, and therefore any increase in income only had a marginal effect on fuelwood extraction. However, when VSS is not in effect, extraction is high any increase in income has a greater impact.

Scenarios outside the Village Forest Area (VFA)

In the model when none of the households derive income through NREGS and the VSS is established, we see an increase in extraction outside the VFA (Figure 10a, Run3). However, if all of the households (i.e. 64) received income through NREGS, we see that the level of extraction is much less (Run 2). As people increase their earnings through other means, they no longer sell fuelwood as their sole livelihood strategy. In the final simulation, we test the likely outcomes in the absence of VSS, but all the households earn additional income through NREGS projects. There is a further drop in the level of fuelwood extraction, and now the extraction is evenly distributed and people are earning more money. In figure 9, we test to see how NREGS might reduce fuelwood extraction inside the VFA by half in the absence of VSS. While VSS reduces levels of extraction inside the VFA, it also increases the extraction outside the VFA. NREGS, 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 income, rather than shifting extraction from a managed and governed forest area to an unprotected area.

Figure 10a: Extraction of fuelwood availability outside Village Forest Area (VFA)

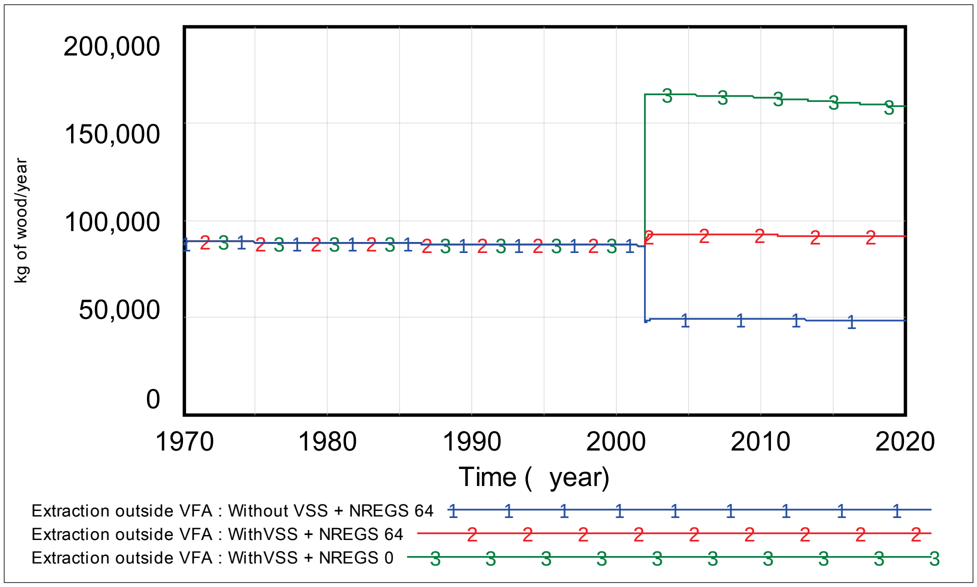
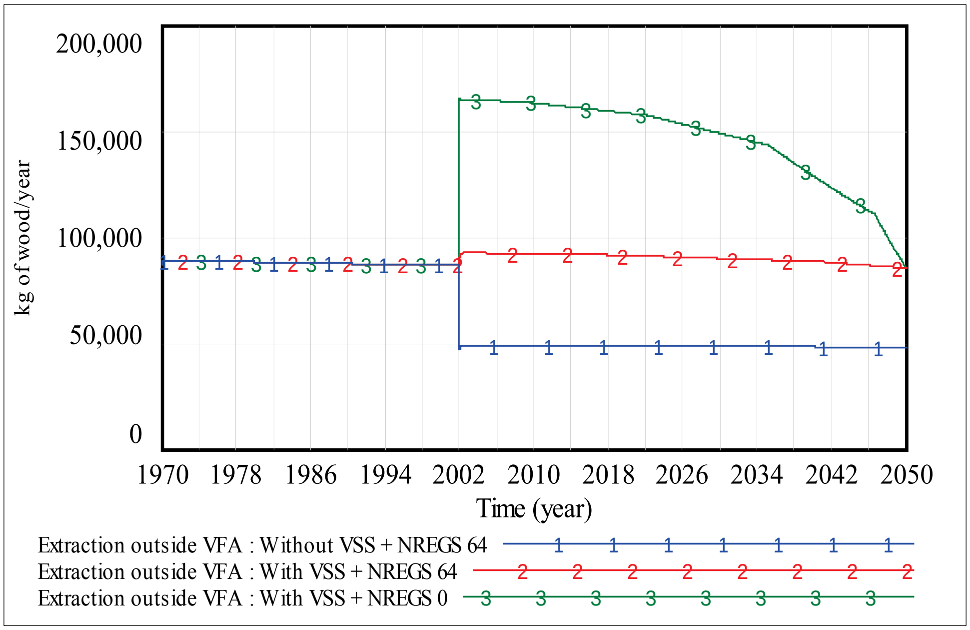


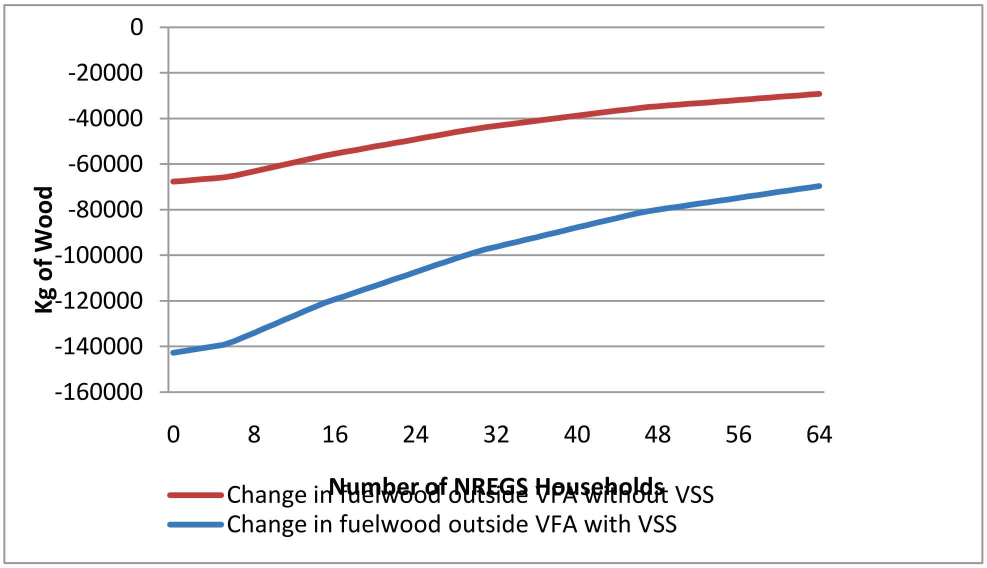
Figure 10b: Extraction of fuelwood outside Village Forest Area (VFA) until 2050



In figure 10b, we experiment with an increase in the time horizon to 2050. In an extended time horizon, we notice that there is a drastic drop in extraction of fuelwood outside the VFA, when there is a VSS in operation, and when none of the households receives income from NREGS. The burden of extraction of fuelwood shifts outside the VFA when VSS is in effect. Through the years as people depended on the forest outside the VFA the stock depletes, making it harder for people to extract beyond a certain point. By 2050, the extraction level is similar to the scenario where all the households are getting income through NREGS. The pattern of behavior, however, is not reduced extraction through reduced need, but instead is reduced extraction through reduced availability.

In figure 10c, as more households participate in NREGS the change in availability of fuelwood between 2002 and 2003 improves. When VSS comes into effect, the change in availability of fuelwood improves from negative 142,733 kilograms of wood to negative 69,707 kilograms. When VSS is not in implementation, the change is still negative but the magnitude is less. Fuelwood availability improves from around negative 67,722 kg of wood to negative 29,236 kg of wood when number of households receiving NREGS employment increases from zero to 64. Outside the VFA, the magnitude of impact of NREGS is opposite to the one inside the VFA. Figure 10c, indicates a significant impact of number of households participating in NREGS when combined with the presence of VSS in Boyapalle. As the number of households receiving income through NREGS increases from zero to 64 under conditions when VSS is not present, there is less movement in fuelwood availability (38486 Kg of wood). However, under conditions where VSS is operational, as there is an increase in the number of households receiving income through NREGS, there is a greater amount of fuelwood available (73025 Kg of wood). Extraction levels increase outside the VFA to meet household income and other needs, when VSS is in full implementation. An increase in income has a more profound impact in reducing

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



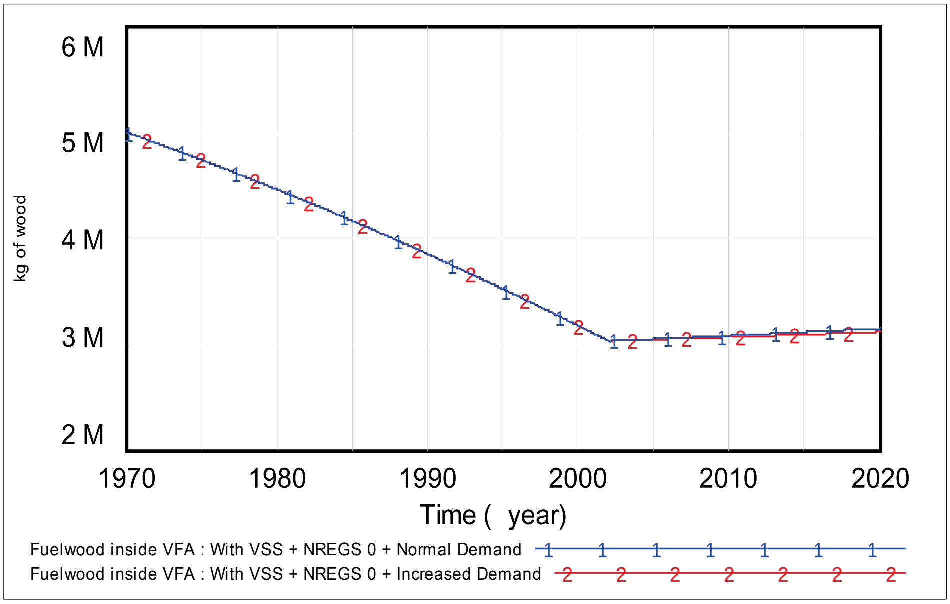
fuelwood extraction levels. From the same graph, it is evident that the stock of fuelwood available is similar when VSS is not operational, and when none of the households are engaged in NREGS. The same is true when VSS is in implementation, and all of the households participate in NREGS.

INTRODUCING MARKET DEMAND

People in Boyapalle sell their fuelwood in nearby Thamballapalle market. The demand for fuelwood increases during election time and other festival times, which results in increased fuelwood extraction. In all previous simulation runs, the market demand from nearby small towns has been kept constant. Now we will examine the impact of market demand on fuelwood availability both inside and outside the VFA.

Scenarios inside the Village Forest Area (VFA)

Figure 11: 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. We had seen earlier (Fig 9) that there is minimal impact on fuelwood extraction inside the VFA with NREGS when VSS is already implemented. Similarly, when there is high market demand we do not see a lot of change 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.

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 6). 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 can be seen in figure 12, by comparing Runs 1 and 2, where Run 2 represents the scenario with increased demand.

Figure 12: Fuelwood Available outside Village Forest Area (VFA)

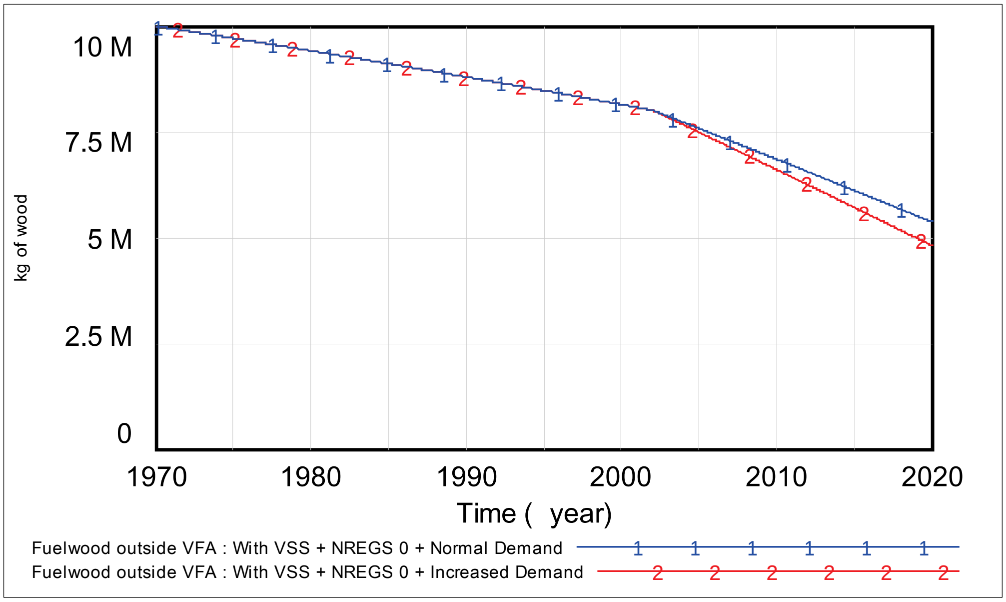
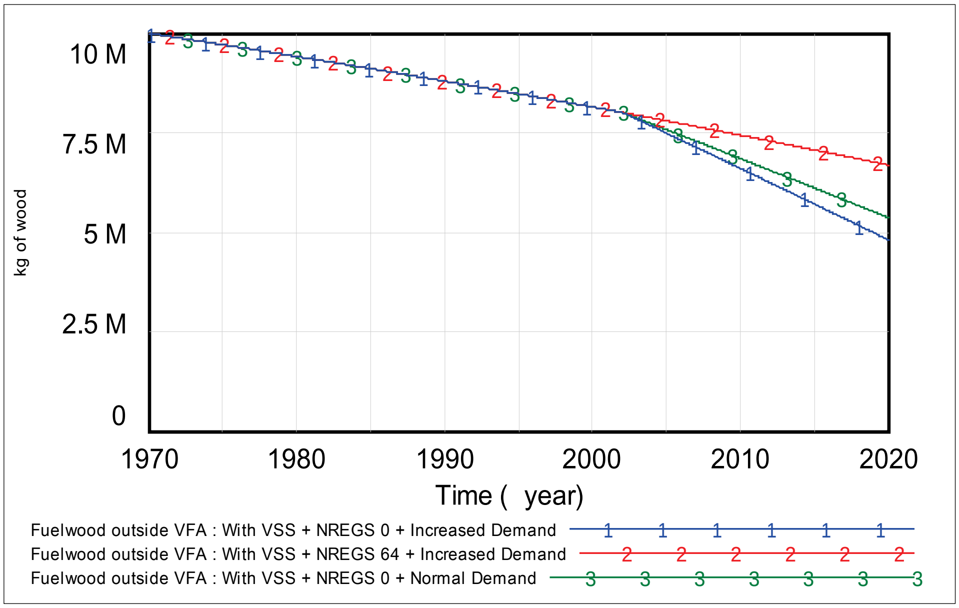


Figure 13: Fuelwood Available outside Village Forest Area (VFA)



However, what would be the outcome if all the households earned income through NREGS. In figure 13, we show that when market demand is increased the trend of fuelwood availability though decreasing is better when all the households have income through NREGS (Run, 2). Since people have access to employment through NREGS, with sufficient income, their need to extract fuelwood from the forest is lower. 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 key in 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, for selling and for 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 14: Simplified version of the Boyapalle Model

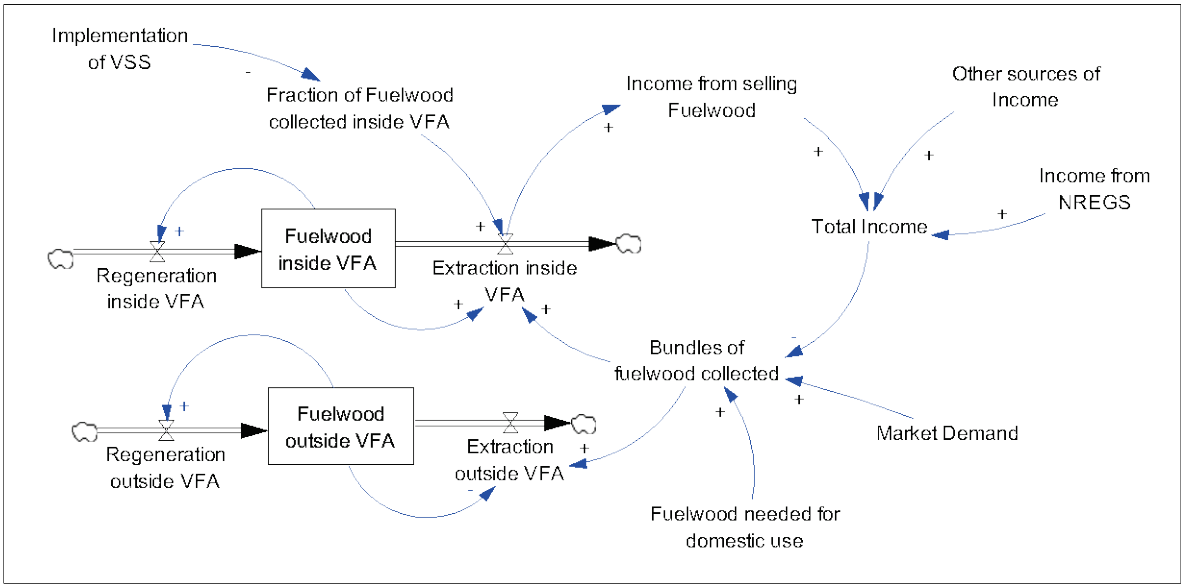


Figure 14 represents a simplified version of the Boyapalle model. The availability of fuelwood is represented as stocks, which can increase through regeneration of trees and decrease through the extraction of wood. One of the important feedback loops in the model is presented in figure 7. People extract fuelwood to supplement their income. As they extract more fuelwood, their income increases, and over time, it slows the level of extraction. When income from NREGS or other sources increases it reduces the need for people to extract fuelwood. Our experiments earlier show that even when all the households receive income through NREGS, the availability of fuelwood is still decreasing. An important question that remains unanswered: what does it take to improve the availability of fuelwood in the forests around Boyapalle? However, it is necessary to understand how extraction of fuelwood is driven by need for income and by domestic needs. Without decreasing the demand for domestic fuelwood, it is difficult to improve the availability of fuelwood.

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