Community Driven Modeling of Social-Ecological Systems: Lessons from Andhra Pradesh, India

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Abstract

In this paper, we focus on our methodological approach of engaging poor communities and households to model the interactions between household livelihood strategies and natural resource dependence, with a particular focus on forest resources. 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. We will describe our methodological strategy of using participatory rural appraisal techniques in combination with group model building to elicit data on a key dynamic problem over time in a forest dependent community in rural Andhra Pradesh, India. Our goal is to develop dynamic models predicated on the knowledge and behavior of actors most directly embedded in particular social-ecological systems. We believe that people, dependent on natural resources for their living, are the real experts to help develop dynamic models of human and natural systems interaction. We outline the four phases in which we use participatory approaches to work with a community to identify a dynamic problem that concerns forest resource dependence and their livelihoods, the associated reference modes that portray the dynamic model, and the way we build confidence in the initial models that emerge from the community. We conclude with reflections on community driven participatory modeling.

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

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but also have a market value. Complexity of household livelihood strategy increases from a simpler intensively cultivated single crop agriculture to more complex resource management involving multiple resources such as multiple crops, forests, pastures, and water resources.

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. It is our contention that experts – academic, government, or nongovernment – may know some of the processes that link social and ecological systems but are poor substitutes for actual households and communities that make daily decisions which over time shape livelihoods and influence local ecologies. The concern then is how best to involve people in eliciting data for model building, and their participation in deriving initial causal loop models describing behaviors across the social and ecological spectrum.

In this paper, we describe effective ways of combining participatory rural appraisal techniques with group model building to develop system dynamic models of social-ecological systems in rural natural resource dependent communities in India. Our focus in this paper is limited to describing the participatory techniques to involve people and elicit accurate data for model building and not on the substantive explanation and implication of our models. We will elaborate on our process of community driven modeling of interactions between households and local forest ecosystems and the value of deploying participatory methodologies for capturing and modeling the dynamic complexity and linkages between social and natural resource systems. Our primary goal is to describe: 1) the use of Group Model Building with rural households and communities to build System Dynamic Models, 2) the uses of Participatory Rural Appraisal techniques to complement Group Model Building in the context of poor rural communities, and 3) the process of building SD models on the basis of knowledge and input from those closest to social-ecological processes including the households and community most directly dependent on the forests.

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 paper, we will highlight the participatory process leading up to our model building; and the critical nature of participatory appraisal technologies for systematic development of dynamic models of social-ecological systems. The paper will first outline the focus of our research, the importance of dynamic modeling of the underlying structures, and process through which we establish and verify underlying structures of community and forest ecosystems interaction and feedback. This work is ongoing, and is done 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: Case of 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.

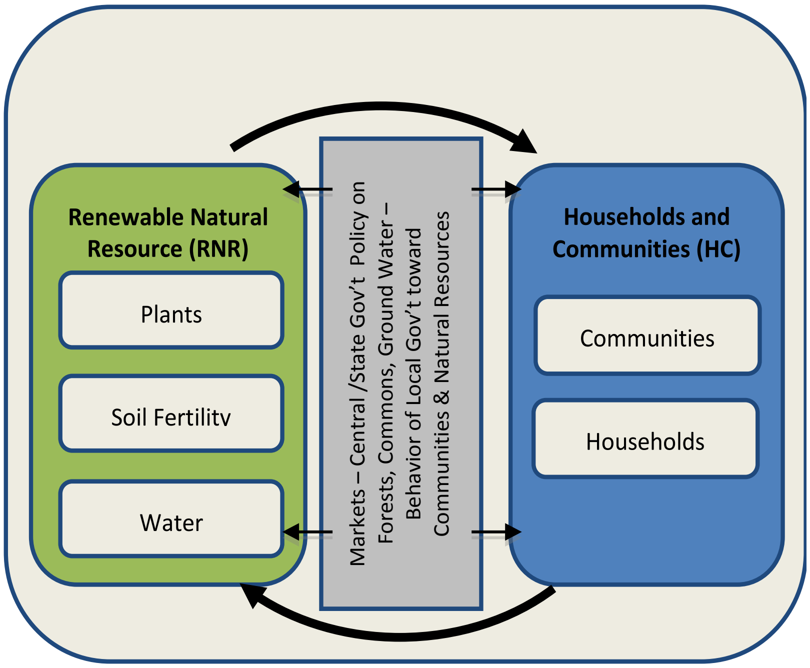
How rural communities protect, manage, and use a community forest will determine not only the condition of that forest, but also other natural resources closely linked to that forest – such as ground water availability in nearby villages, or soil fertility in adjacent agricultural lands. In Kenya, highland 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).

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



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 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 poorIn this paper, we will focus exclusively on the participatory processes and inclusive group model building that we conducted in Boyapalle village of Andhra Pradesh. We will outline in some detail the way we developed reference modes associated with a dynamic problem. The difficulty in executing field based dynamic modeling, and considerable progress we have made in doing community driven dynamic models. We will first describe the village, our approach to sharpening our understanding of the dynamic problem from the perspective of key stakeholders including the village. We will then outline our approach to engaging the villagers in defining and identifying supporting data to establish a case for the dynamic problem, associated reference modes that are indicative of the dynamic problem. We will also describe the triangulation methods, and other participatory appraisal techniques deployed to deepen the case study, develop the system dynamics model, and build confidence in our models against time series data from a variety of sources.

Methods and Process for Engaging Community and Identifying the Dynamic Problem

We deployed a suite of participatory action research techniques to gain access to community, trust of households, and subsequently identified the dynamic problem from the perspective of villagers. Once the dynamic problem was identified, we then used a suite of participatory rural appraisal techniques to establish relevant reference modes. The process, however, began with a wide ranging discussion with professional staff of Foundation for Ecological Security (FES) who were keen to begin ecological restoration in collaboration with Boyapalle community. Our fieldwork to model the drivers of fuelwood extraction and availability could be roughly divided into four phases. Phase I, the modeling team and FES staff met at their head office to discuss the advantages of system dynamics modeling of problems at the intersections of communities and local forest ecosystems. Moreover, we also discussed and debated the nature of dynamic problems confronting communities in close proximity to Sadhukonda Forest Reserve in Andhra Pradesh. In Phase II, we deployed a team in Andhra Pradesh within the Papagni Regional office of FES.

This team of local professional staff and graduate students were given the task of identifying communities in close proximity to the forest reserve, and delineate a forest boundary that the community is actively engaged in using and managing. In this process, they identified Boyapalle village and utilized participatory rural appraisal techniques to define and develop a shared understanding of a dynamic problem prevalent in the village. The case map of Boyapalle, with associated trend lines and behavior over time graphs were developed in phase II. In Phase III, a larger team of FES professional and field staff, dynamic modeling team, and Boyapalle villagers coalesced to build confidence in the initial dynamic problem that was identified in phase II. More villagers, different types of data, and a variety of PRA techniques were deployed to triangulate the dynamic problem and supporting data before we could identify the structures underlying problem. At the end of Phase III, we had a preliminary structure of drivers explaining declining fuelwood in Sadhukonda Forest Reserve adjacent to Boyapalle community. The overall structure and specific sub-structures were discussed and shared with groups of villagers, and confirmed. In Phase IV, we began collecting monthly data from a sample of households in Boyapalle village to build further confidence in the dynamic models developed in collaboration with Boyapalle community and FES, and to begin tracking changes over time in key drivers identified in these models.

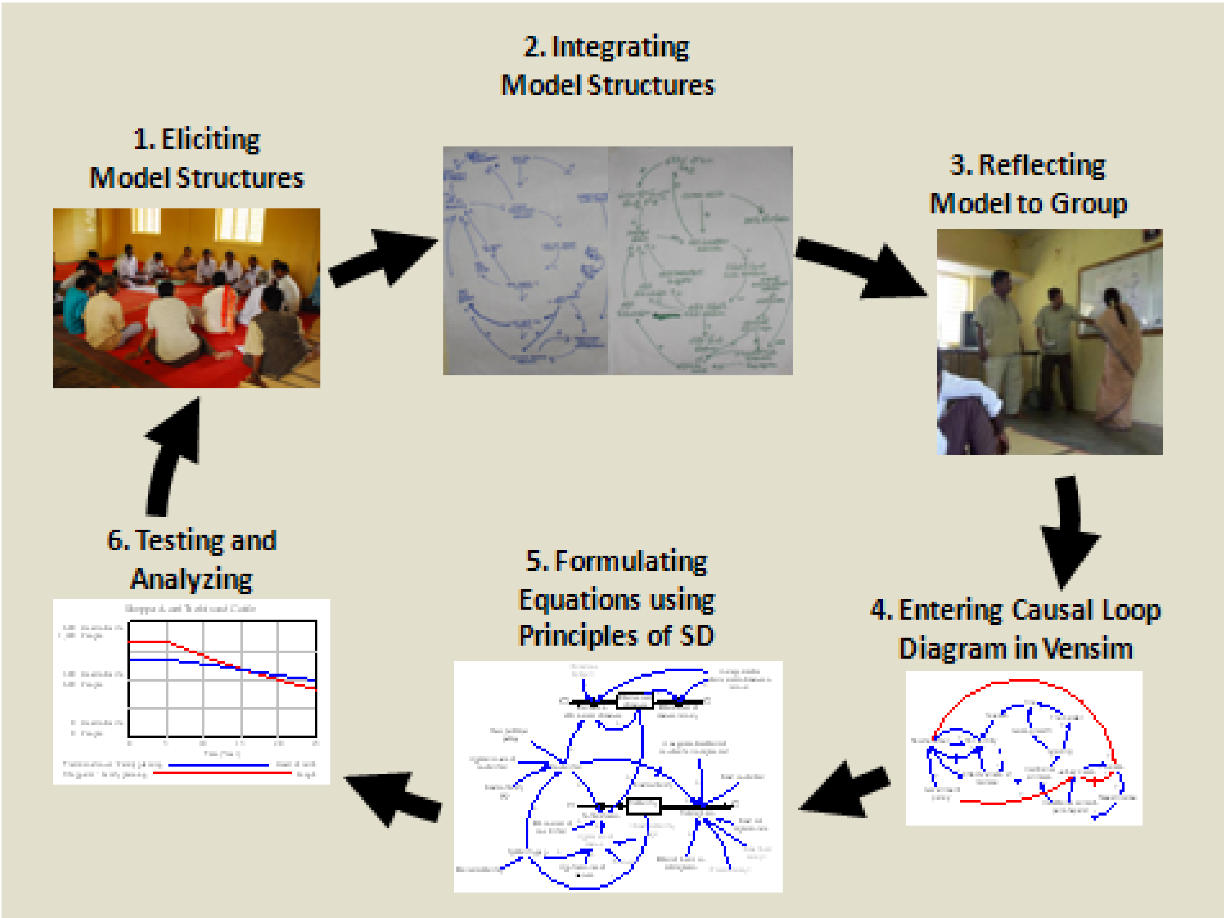
Phase I: Role and Use of SD Modeling in Ecological Restoration Work of FES

Phase I was important for laying the foundations for the possibilities and problems of engaging in system dynamics modeling in the field. The goal was to generate a nuanced insight into what dynamic modeling holds for an NGO such as FES in addressing ecological restoration problems at various spatial and temporal dimensions. This phase was interactive and iterative between the modeling team and FES professional staff. The entire phase was about understanding the role of dynamic modeling and advantages for FES in their village level interventions. In large part, Phase I was also about identifying robust and extant data that would give us confidence in identifying a dynamic problem in specific communities where FES is working and inform the reference mode that we might model.

At the end of Phase I, we decided to focus these same questions in a specific region, forest ecosystem, and communities that FES is about to intervene in. The general discussion about dynamic problem shifted to the nature of the problem in Sadhukonda Forest Reserve in Chittoor District. FES' Papagni Regional Cell had been working on this forest reserve and there was considerable data from previous vegetation studies, and satellite images over three time points. Over a two-day period, it became evident that examining changes in biomass, in aggregate, was insufficient to understand the problem from the vantage point of a community. How does a community perceive changes in that forest reserve? How do they engage with the forest in close proximity to their village? Do they see any relation between changes in their livelihoods and changes in the forest reserve? To clarify the dynamic problem, and develop a reference mode to model, we had to move closer to the ground where we can observe and understand constant interaction between communities and local forest ecosystems. It was evident that even discussing these processes at the level of the entire forest reserve was at a scale much too large. We had to locate our community driven modeling in a specific community that is using a specific area of the forest reserve. It took us three days where we struggled with a clear definition of the dynamic problem, and realized that unless we locate our modeling in a specific community, we will be unable to capture the complex interplay between people, their livelihood strategies, and dependence on forests.

At the start of Phase I, we had a modeling process in mind, developed based on a previous pilot study to model a problem with villagers and test the process for community driven modeling (see Figure 2). We began our modeling using this sequence of steps but with new learning from interactions with FES and local communities, we modified the process. We added several steps to this process after our experience with identifying and establishing a reference mode for a dynamic problem in Phase I. There is now a greater emphasis on problem definition and participatory techniques of generating a reference mode when extant data are not readily available. These two explicit steps prior to eliciting model structures are critical given the importance of identifying and agreeing on the nature of dynamic problem, and the scale at which to locate the modeling process.

Figure 2. Dynamic Modeling Process from the First Pilot Study



Phase II: Developing Case Study of a Specific Community and a Dynamic Problem

Boyapalle Village: Context and Location

FES has been a key stakeholder in this project from the beginning because of their experience in working with social and ecological systems coupled with an interest in system dynamics. FES took the lead in identifying the villages where we would undertake dynamic modeling of livelihoods and local forest ecosystems. It was evident that some communities were far more dependent on Sadhukonda Forest Reserve than others were, and FES was keen to undertake group model building in such communities. Their interest was to work in one of these forest dependent communities living close proximity to the Sadhukonda Reserve Forest, with whom they had not worked in the past. Boyapalle is one such village with high dependence on forests for their livelihood and FES had been planning to work in this village on ecological restoration. Boyapalle was an ideal village in terms of FES's interest. They had conducted several PRA exercises in preparation of work in Boyapalle. We gained immensely from this data, as it provided much needed understanding of the community. PRA exercises and insights from the social and resource maps produced by FES (See figure 3a and 3b) were immensely helpful in our entry into Boyapalle to determine the dynamic problem, associated reference modes, and subsequent group modeling work with the villagers. Participatory Spatial Models of

Boyapalle – social and resource maps – will be useful as we go forward in our modeling work in Boyapalle. They will provide a comparison with future social and resource maps and lend additional insights to our system dynamics models.

Boyapalle village is located on the periphery of Sadhukonda Reserve forest (SRF), in the western part of Chittoor district, Andhra Pradesh, India. Boyapalle has 63 households and a large number of the households rely on dryland agriculture of peanut farming. The village has access to an all season road and is six km from Thambalapalle, a small town with a regional market. Thamballapalle has a post office, bank, and a health clinic. Within Boyapalle village, there is a community hall, primary school, two hand pumps and four bore wells that provide drinking water. Most of the houses in the village are constructed from concrete and bricks and are electrified. All of the households in the community are from a 'backward caste.' The education level in the village is low with an average education of two years per person. There is, however, a growing trend of parents sending their children to school.

The average annual household income ranges between USD 300 to 450, and people depend on agriculture and wage labor as their primary source of income, whereas selling fuelwood, fruits, and flowers and animal husbandry are secondary. Due to small land holdings (2.8 acres per household) and low productivity, annual income from agriculture is approximately $ 174, which is insufficient to support a five-member household. Twenty-five percent of the households that are landless depend on daily wages and sale of non-timber forest products (NTFP) throughout the year. Supplementary income from forests and wage labor are critical for sustaining household livelihoods in Boyapalle, irrespective of the size of landholding. Further, drought has affected the community in recent times (2000-2003) leading to the forced sale of cattle, sheep and goat due to shortages in fodder and water. Only 3% of the farmers in the village have irrigation to realize better crop yield from their small land holdings. Erratic rainfall patterns have limited the success of agriculture as the dominant livelihood strategy in Boyapalle. This has placed added pressure on the forest as households rely on selling fuelwood not only for supplementary income but also as a predominant source of income.

Participatory Spatial Models of Sadhukonda RF

Social and resource mapping are highly participatory and build trust between outsiders and villagers in the process of identifying habitation and natural resources patterns. In order to identify the dynamic problem and arrive at a shared understanding of that problem, we had to understand the way villagers' related to Sadhukonda Reserve Forest. Participatory modeling techniques that engage people in building three-dimensional models are ideal for delineating the physical features of Sadhukonda forest and sharpen our understanding of the way Boyapalle habitation relates to the forest (see Figures 4a and 4b).

FES staff conducted focus groups and engaged seven members of the Boyapalle village representing different social and economic strata in building a three-dimensional model of the forest. The primary goal of this exercise was to understand how the community perceives the problem and arrive at a shared definition of the problem followed up with building the model of the forest. They identified declining fuelwood availability as a dynamic and a very important problem during the focus group discussion. They defined the problem in terms of their perception of the availability of fuelwood in the forest and elaborated on the problem using indicators such as time taken and distance travelled to collect fuelwood. After understanding the problem, we conducted an exercise to draw behavior over time graphs to inform the reference mode for building system dynamics models. We combined two PRA methods to accomplish this behavior over time graph – establishing a time line anchored in major events as told by the people of Boyapalle habitation and a trend analysis of changes in fuelwood that tracked along the time line that they previously developed. We asked questions with reference to a particular time line based on established landmark years of different ruling political leaders or regimes to facilitate the discussion (Kumar, 2002). While developing the time line is much easier given the collective memory around major events and particular year of that event, developing trends or changes in fuelwood availability over this time is hinged on skillful elicitation by FES staff familiar with the villagers. Collaborative system dynamics modeling with a nongovernmental organization that is firmly implanted in local processes, culture, and politics is paramount; it ensured that we were able to establish reference modes with people's participation (see Figures 5 and 6).

Figure3a: Boyapalle Social Map prepared by FES in 2004

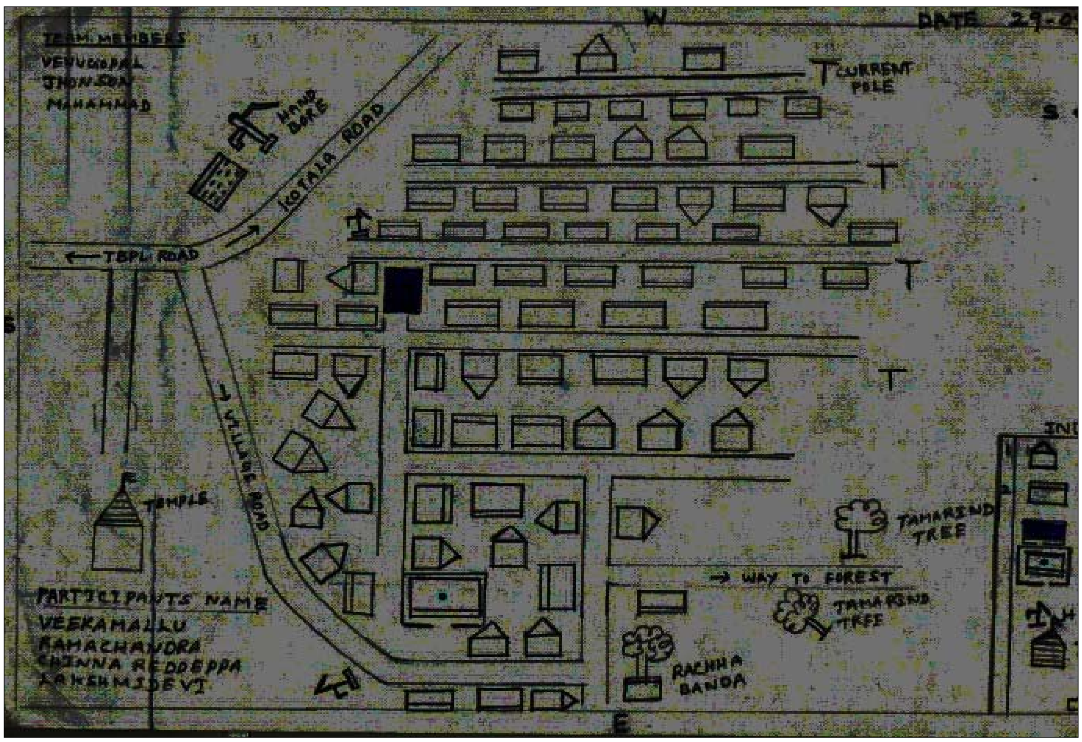
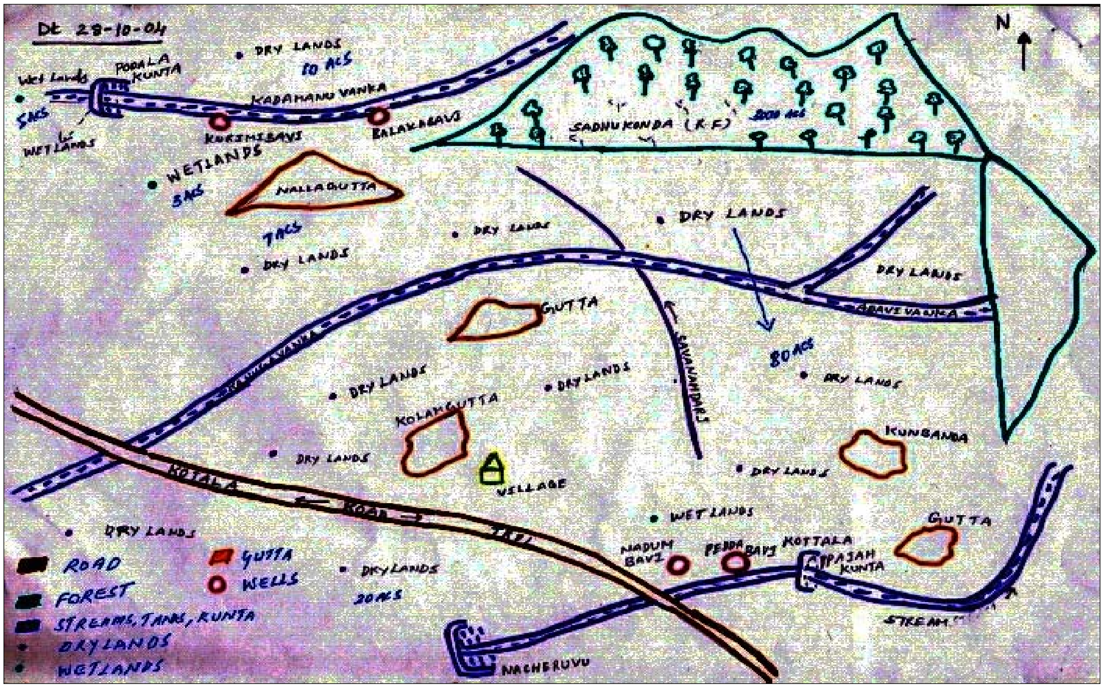


Figure 3b: Boyapalle Resource Map prepared by FES in 2004



The same villagers from Boyapalle also built a three-dimensional model of Sadhukonda Reserved Forest. A central aspect of this PRA exercise was to build a three dimensional model of nearby Sadhukonda Reserve Forest (SRF) and mark various attributes of the landscape using the model (see figures 4a and 4b). The goal is to represent trends in fuelwood availability, time spent to collect fuelwood in three-dimensional space. In building a model soon after the focus groups to identify timelines and trends, the villagers are better able to show the distances that they travel now to collect forest resources. As they continued into the model building, they were also able to identify the specific areas where they extract fuelwood from, and changes in the distances they walk to extract fuelwood and

Figure 4a: Community Members Engaged in Participatory Spatial Modeling of Sadhukonda Forest Reserve

other forest products. This process was enormously helpful in identifying the boundaries of the forest they use, adjacent village lands, and other attributes of the forest.

One of the goals of using participatory approaches is to get people involved and draw key insights from these exercises. Our core belief is that dynamic modeling built on information from those most involved in environmental and social dilemmas will result in products that are most useful for subsequent policy and program intervention. In using a suite of participatory action methods, we were able to involve different actors in deeper ways to give shape to the dynamic problem and the reference modes. We observed that some participants were more involved in discussions during the focus group to establish timelines and trend analysis of fuelwood in the forest, whereas those who were more reserved during the discussion time, took a more active role in building the three dimensional model of the forest reserve. Including all participants through different methods to elicit information on the dynamic problem is critical for developing dynamic models that are relevant to people. We accidentally realized this advantage of using a variety of participatory methods to elicit similar or related information is also advantageous in engaging different stakeholders. Seeking different methods to engage a spectrum of stakeholders in dynamic modeling should be standard practice.

Figure 4b: Completed Three-Dimensional Model of Sadhukonda Forest Reserve indicating location of houses, mobility paths into forest for extraction forest resources

Once the model of Sadhukonda forest was built, people assigned relative scores to their perception of fuelwood availability in the past, using sticks; more sticks indicated greater abundance of fuelwood in a particular time on the timeline. The number of sticks corresponded to a relative score, which was recorded during the exercise. Using these scores, we developed behavior over time graphs, which gave us insights into their perception of the problem. It also provided an opportunity for the community members, FES staff, and the research team to arrive at a consensus about the dynamic problem that the model would address.

Reference Modes and Behavior over Time Graphs

The participatory exercises – spatial and temporal – gave us confidence in the nature of the dynamic problem. Using the information from the initial interactions, we developed a household survey to understand if other villagers shared these perceptions of the dynamic problem. We planned to collect retrospective data starting from the 1970s to understand the trends of fuelwood availability over time. One of the major challenges was the villagers' comprehension of time. Since most of the adults in the village were not educated, they did not recognize the concept of specific year. In order to establish a common understanding of time we developed a time line based upon important events that corresponded with a particular year. The previous time line was not adequate because it referred to a general time-period that could span a few years (such as when a particular person was the Chief Minister of Andhra Pradesh), rather than a particular year.

We wanted a more specific year pinpointed to help the respondents recall the data. So we focused on a time line of major events that were specific to the community. First, we began with community members listing major events that occurred in the village. After we had the list, we consulted with literate members of the village to give the corresponding years for particular events. At the end of the exercise, we had a column of events and the corresponding year when the event occurred. This exercise standardized the time line (See table 1). For example the primary school was built in the village in 1982, so we asked a question about the availability of fuelwood during the time when the primary school was built. It was easier for the people to recollect this data, and for us to assign a particular year for fuelwood availability.

Table 1: Standardized Time-line for Household Survey

Event	**Year**
Pipeline installed in the village	2008
Community hall was built	2002
First concrete house was built	1996
Primary school built in the village	1982
Largest fire in the village in recent times	1972

After establishing the time-line, we conducted a household survey. The questions on the survey were based on insights from the focus group and the PRA exercises. We sampled only those individuals who were forty years or older because the behavior-over-time graphs from the PRA exercise had a time horizon going back to the 1970’s. There were 30 such households in the habitation, and we surveyed 25 of them. Along with a few socio-economic and household composition questions, we asked questions about the availability of fuelwood, Bodha grass, NTFP, and timber during previous years. These data were used to develop behavior over time graphs, which were compared with behavior over time graphs from the PRA exercise. This was especially helpful to bolster our confidence in the behavior over time graphs and to understand if other members of the village shared a similar perception of those who were involved in the PRA exercises.

The two graphs were placed together for comparison. These were not two separate graphs but rather one was a more refined version of the other. The first discussions with the community gave us an idea of the dynamic problem. This was followed by PRA exercises through which we used a more detailed approach to understanding the dynamic problem through behavior over time graphs. We needed to verify if the behavior over time graphs built with seven members of the village through a PRA exercises would coincide with a graph built through a more quantified method using survey data collected from other members of the community. In Figure 5, we show two different graphs where HHS refers to the graph developed using data from household surveys and PRA refers to the graphs developed from the PRA exercises. PRA LB and PRA UB refer to the lower and upper bound of the graph. The two graphs were developed using different methods with different people but have similar trends. Respondents indicate that fuelwood has become significantly less available over time. Likewise, since 1972, the distance travelled and time taken to collect one head-load of fuelwood has steadily increased (Figure 6). While the household survey suggests that fuelwood availability may have started to recover in recent years, the PRA exercises and other indicators suggest that fuelwood availability has at best stopped declining. In neither case has fuelwood availability recovered to earlier levels. This supports the initial discussions that the dynamic problem of interest for the people of Boyapalle is declining fuelwood availability. Behavior over time graphs in Figures 5 and 6 are complementary but it is important to note the difference between these two. The distance travelled and time to collect fuelwood are proxies for fuelwood availability and are not the problem itself. Community members used these proxies to explain the problem. If the distance and time were the dynamic problem, we would focus on improving the paths taken to collect fuelwood rather than the availability of fuelwood. Hence, availability of fuelwood was the dynamic problem and the behavior over time graph in Figure 5 was used as the reference mode for System Dynamics modeling.

These initial interactions between the researchers, FES staff, and community members helped to identify the dynamic problem and develop reference mode for the model but also were very significant in terms of establishing trust and deep familiarity, which were important for later phases of the project. Open communication and our emphasis and eagerness in highlighting their perspectives of the problem enabled us to visit the community repeatedly with surveys and models.

Emergence and Development of a Detailed Case Study

After the reference modes were established, we worked to document the process and prepare a case study. During this process, we gathered detailed information about the community. We collected information regarding its location, infrastructure, demography, livelihoods and economy, and the presence of institutions within the community. This step helped us build on the relationship with the community and develop a deeper understanding of the system and processes that govern the interactions between the social and the ecological systems in Boyapalle. We used another PRA tool, the “Transect-walk” to get a better picture of the fuelwood situation described by the community members. Transects provide a cross-sectional view of natural resources at different elevations, or ecological zones. They also verify information that has been generated through social and resource maps or other PRA techniques (Kumar, 2002).

We went to the forest with a community member who acted as our key informant. He guided us through the same path that villagers take to collect fuelwood. We recorded GPS co-ordinates every 20 minutes and created a map to show how far community members go to collect fuelwood. It also provided us with the chance to verify the data on distance travelled and time taken to collect fuelwood. Information gathered during this process was especially helpful to develop hypothetical explanations of the reference mode. This deeper understanding was very useful during development of the system dynamics model as it provided us with rich stories to bolster confidence in our models. The case study was later used as an initial document to inform all the members who attended the system dynamics modeling session of this project. The nearly seventeen-page document provided everyone with the context for the dynamic modeling sessions. The case also introduced the participants to key terms such as the dynamic problem, reference modes, and behavior over time graphs. Rather than understanding these terms through definitions, they could relate these terms to their day-to-day practice through descriptions in the case study, which made it easier to learn and contribute to the model building. The case study was essential for bringing all participants to a similar level of understanding and provided vital information for the modeling process.

Figure 5: Behavior over time graphs for fuelwood availability

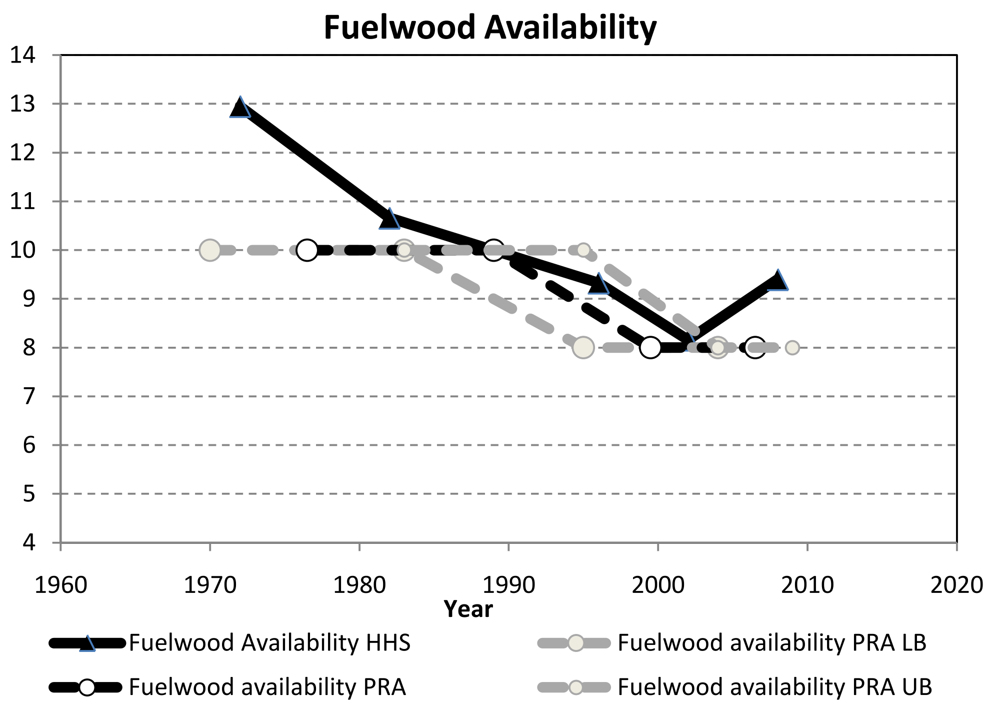
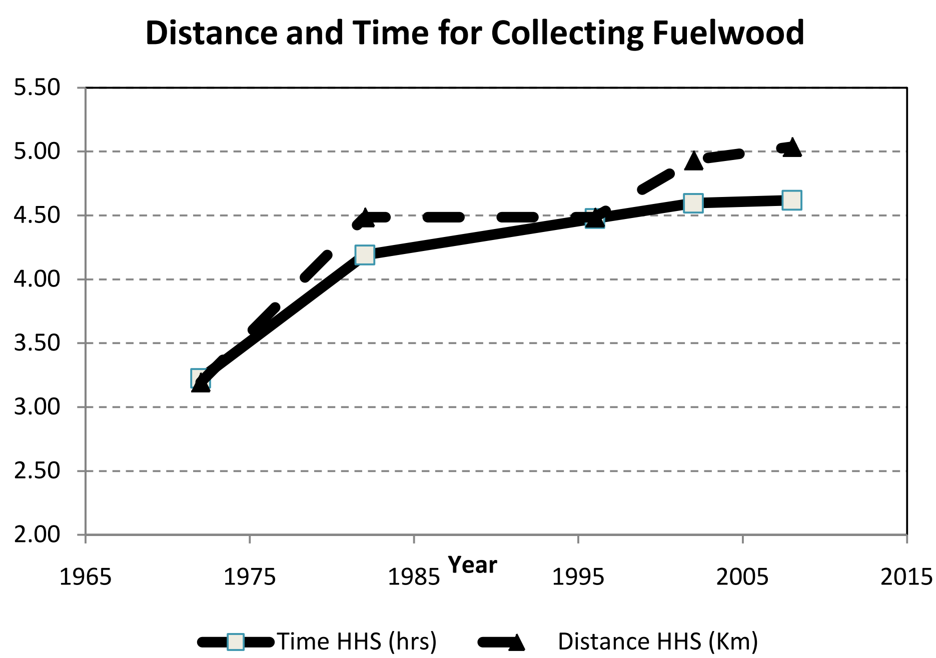


Figure 6: Distance travelled and time for collecting fuelwood over time



Phase III: System Dynamics Modeling in the Field

One of the milestones of the project was the system dynamics modeling group that was brought together to model the drivers of fuelwood availability in Boyapalle. This was an integrated group of a system dynamics professional expert in modeling, combined with professionals from FES at all levels from the village to the head quarters, faculty with expertise on community and natural resources, and graduate students. The project was based on building the SD capacity of the FES staff and developing a model through interactions among the staff, community members, and researchers. The workshop was an essential aspect of meeting those objectives. FES staff from different regional offices along with researchers and graduate students gathered about an hour away from the field site. The whole group was divided into three sub-groups. First group focused on building the model (Core modeling team), second group was focused on information exchange between the community members and core modeling team (Community team), and the third team collected the plant data in the forest to develop a plant stage model (Plant team). There was also a management team, which had members from all the three different teams represented. The Management Team, discussed findings from all the three teams and progress for the day, and planned the modeling, data gathering, and field logistics for the next day. Phase III could also be thought of the group model building phase with participants. Potential participants have already been identified, but we move toward presenting the reference modes, elicit variables and structure, formulate a model, and simulate, test, and analyze the model. In this project, we made some preliminary simulations but the models require further testing and analysis to move toward policy and program design strategies.

The core modeling team mainly built the model. We conducted multiple group model building sessions and elicited structures from the team. These structures were later integrated to form a larger model. During this process, the community team would take the models to Boyapalle and bring back vital information and feedback as given to them by the community members. This iterative process provided significant insights from the community members. These insights were incorporated into the model and were again taken back to the community for reflection. This process was resource intensive, but was imperative to build confidence in our system dynamics modeling (see Figures 7 and 8). The modeling workshop was a significant part of the project for many reasons. First, it introduced SD to the FES staff through a project-based group learning process. The project was based on work that is underway in the field, and made it easier for them to relate SD to their day-to-day ecological restoration work in this region. FES has been working in this arena for a long time and SD gave them an opportunity to share their mental models of the problem, and improve them through shared knowledge. Inclusion of staff at different levels within the organization created a buy-in and paved the way for future collaborations in similar SD modeling projects. From the model point of view, the SD workshop held special significance because it ensured that the model was built based on key stakeholders embedded in the system and experiencing the dynamic problem and the experts who have been working with the system for many years.

Phase IV: Monthly Household Data Collection

Collecting data

Using the model built at the workshop, we created household surveys to collect data that would both give us trend data on key drivers in the model and create other reference modes for building confidence in our models. We used the model to inform the surveys by listing all the variables implicated in the model. The household survey is being administered in Boyapalle village every month. We are collecting data regarding the extraction of fuelwood and other related variables on household livelihood strategies. We also developed a market survey to assess external demands for forest products that in turn drive some of the processes of extraction within Boyapalle village. The market survey is being administered monthly in nearby Thamballapalle market where fuelwood is being sold. We have collected data for four months and have begun to analyze them.

Developing the Model

While the focus of this paper is to explain participatory methodologies to build community driven dynamic models, we also wish to provide a brief window into the modeling process that emerges from that exercise. Our larger causal loop and stock flow model is now decomposed into smaller sub-structures. Testing and analysis is easier with each sub-structure. Once each sub-structure is tested and analyzed, our plan is to integrate all of them. Fourteen sub-structures are built from the original model and developed into specific simulation models. Each sub-structure has its own document of model specification, which lists all the variables in the structure and describes the behavior produced by the structure. The sub-structures are now in the process of being tested and analyzed. The model will have the potential to identify key leverage points for intervention, build insights regarding the feedback loops, simulate future behavior, improve understanding of variability in the system with change in input, and identify threshold levels for the system.

Conclusion

In deploying a suite of participatory rural appraisal techniques to develop reference modes from the perspective of villagers, we depart from a tendency to build dynamic models predicated on objective data and data from experts. The advantage of using inclusionary methods of group model building is obvious; deriving credible models from people embedded in the social dilemma. Credibility of these models is directly due to the deep involvement of people in all phases of the Group Model Building process. In the process of using inclusionary methods, we also influence the way villagers themselves develop shared understanding of the systems they influence over time, and cross system interrelationships. Share mental models that link individual household behavior to collective outcomes on the commons (forest commons in our study) have the great potential to instigate community reflection on individual and collective outcomes of their actions over time. Such reflection increases the possibility of coordinated action to address the sustainability of commons that bears a direct relationship to the sustainability of household economy and vice versa.

Lessons from participatory modeling have been along three directions: a) increased clarity and understanding between the modeling team and regional and local FES teams about the definition of the dynamic problem, and the scale at which to model the dynamic problem; b) firmly establishing us in the community to examine with households and community the dynamic problem of fuelwood availability and extraction over time from local forest; and c) affirmation of the value of households and community as experts and their central place in developing initial case study and reference modes, and eventually a system dynamic model of fuelwood availability and extraction. Our experience in these three broad areas led to a refinement in our modeling process and a greater emphasis on problem definition and development of reference modes. In Figure 7 we present our new cycle in the modeling process and in Figure 8, we elaborate on this cycle and show the sequence of steps.

Figure 7. Modified Modeling Sequence from Field Experience

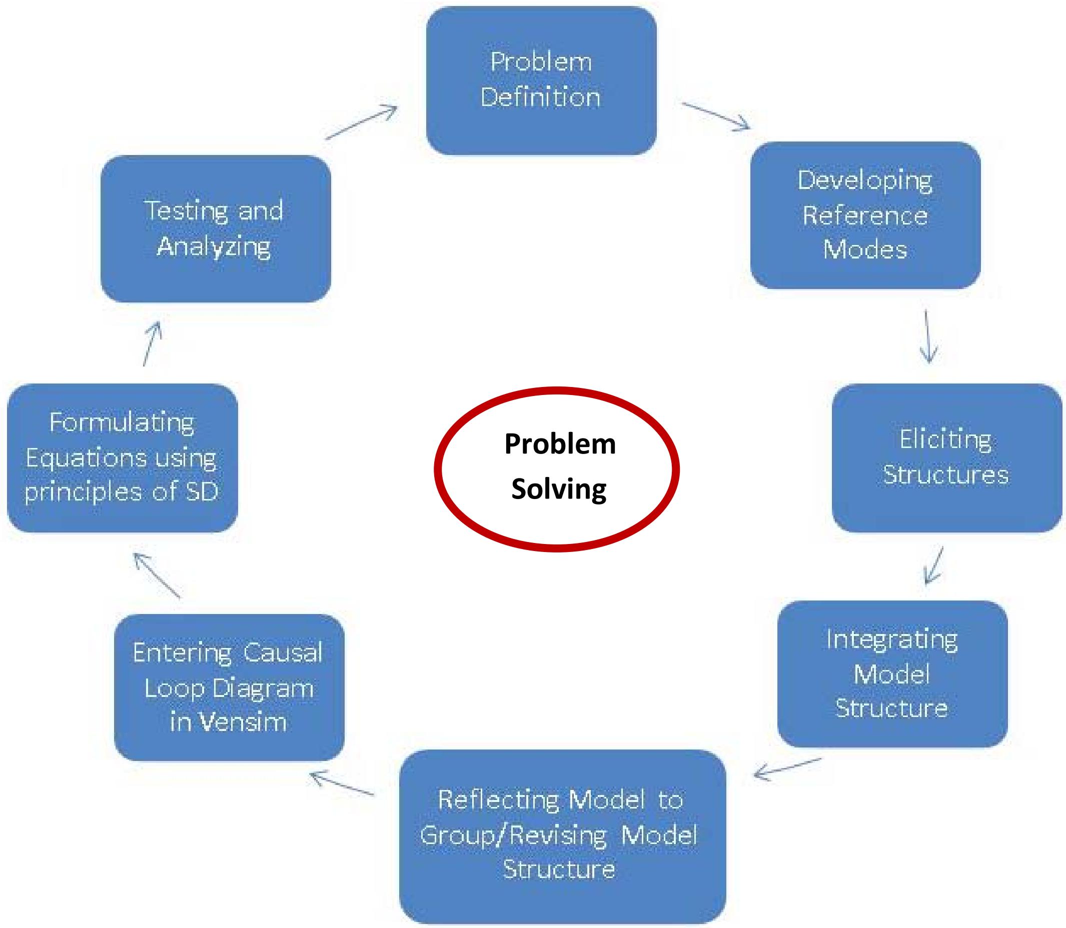
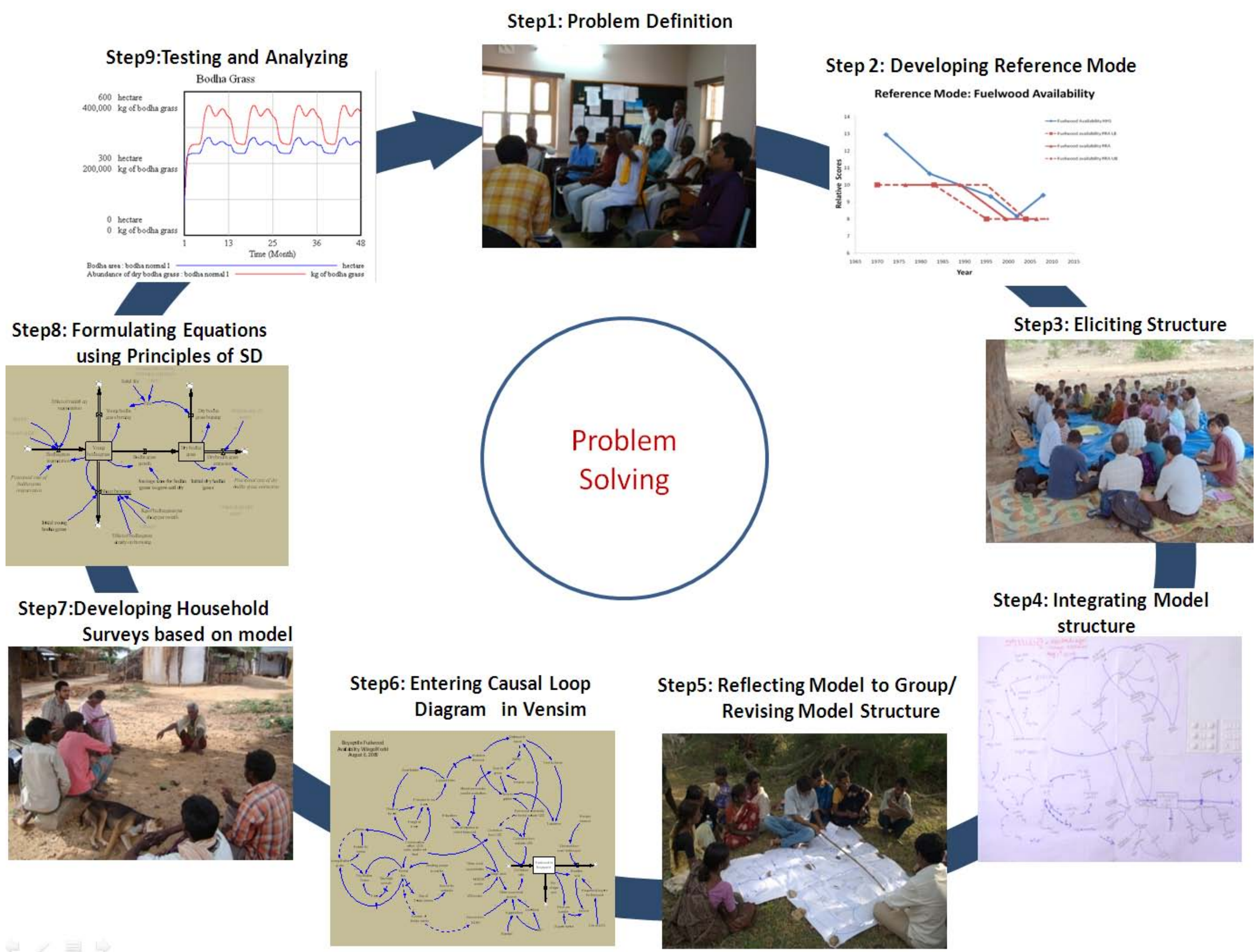


Figure 8: Specific Sequence of Steps in the Modified Modeling Cycle



Our participatory approach had a significant impact in introducing the value of system dynamics to FES and the utility of deploying systems thinking to address ecological restoration within the context of social-ecological systems. It began with a reconnaissance trip to identify a specific problem of concern to FES, the scale at which the problem manifests, and relevant data to establish the problem and the reference mode. In the beginning, there was much confusion and disagreement among FES staff about fuelwood availability and decrease over time being the central problem defining people and local forest interaction. Regional staff from Andhra Pradesh were portraying increasing fuelwood extraction and a declining fuelwood availability in the villages surrounding Sadhukonda Forest Reserve. On the other hand, others at FES were sure that calculations of biomass availability indicate an aggregate increase across the forest reserve.

At a general level, there was a shared understanding that rural poor depended on fuelwood for their energy needs. As we began outlining and substantiating the problem, there were varying articulations of the fuelwood problem depending on the scale at which we examined availability of fuelwood. As we worked through the definition of the dynamic problem, there evolved a better understanding between FES and modeling team and a regard for perspectives on fuelwood availability at a much finer scale (perhaps at the village or habitation level) and not in the aggregate at the level of a forest reserve. It was clear that we had to begin defining the dynamic problem at a finer scale and generate data to establish a reference mode from the perspective of a particular village. These discussions unfolded over three months that began with the reconnaissance visit to FES and persisted right into the field when we began involving the villagers in establishing a reference mode to group model building with villagers. The modeling team relied on FES' new understanding of modeling team's concern for developing a reference mode at the level of a single habitation. Local grassroots organization of FES was instrumental in the process of developing reference modes and necessary for collecting data from the households in Boyapalle village.

Soon our understanding of the dynamic problem was again shifting as villagers were presenting their view of fuelwood scarcity, availability, time and distance it took to gather wood for selling and household use. It became evident that it is difficult to identify and agree on a dynamic problem between villagers who are deeply embedded in the problem, the nongovernmental organization working to address the problem, and the modeling team. Gaining perspective on a problem is difficult when livelihoods are at stake. Unlike problems that are routinely analyzed by experts and modelers, villagers and social change advocates alike are not dispassionate about the dynamic problem. While engaging such actors provides accurate data and portrayal of the problem, it is considerably difficult to define the dynamic problem itself. Engaging households and community in defining the problem gives us enormous confidence in knowing that we are modeling the right problem and in the quality of data that we are able to gather in building models as we move forward. We signal the high value we place on the information and data that households and community provide in giving them a central role in the group model building exercises.

Over time, we arrived at shared mental models between the modeling team, FES staff, and villagers. Our "community driven" philosophy towards model building guided our arrival at shared mental models. A significant impact of our community driven approach to system dynamics are shared mental models of the problem of forest commons among the villagers and between villagers and FES professional staff. Shared mental models were not only about the specific problem we were modeling but also about the larger motivation for examining these problems and ways of intervening in them. Our ability to engage the village in long-term household surveys on livelihood and resource use changes was only possible because of the participation of different stakeholders in developing the reference modes and our use of participatory action research to build system dynamic models.

The mental models of FES staff about biomass availability in Sadhukonda Forest Reserve were based on understanding the forest at a different level – that of the whole reserve and not specifically at the level of Boyapalle village. Mental models of people are generally indistinct, messy, and incomplete which contribute to ineffective policy and programs (Norman, 1983 p.14). Understanding and refining the mental models that are aligned and consistent with the structures and behaviors in the real world is a central motivation of the process of including all the relevant stakeholders. Our goal is to work towards better decision-making and right interventions to address the problem.

A recent study conducted by FES on biomass availability indicates that the total biomass in the forest was increasing. FES has been working with particular villages around this reserve, but on the assumption that biomass in the forest reserve as a whole was on the decline. Our case study exercise and inclusion of households and community in assessments of biomass, however, reveal and different reality for the people of Boyapalle. Fuelwood availability, according to the villagers has been on the decrease. If FES begins their work in Boyapalle with a view that biomass is increasing in the forest, which is not the perception of the villagers, there is greater likelihood that even well intended interventions have a greater chance of failure. Any interventions thus implemented by FES in the village with a flawed mental model could be ineffective or even harmful. The importance of including people in deriving fuelwood data to elicit the dynamic is underscored in this instance of incongruent mental models held by villagers and FES working with them to restore ecologies to sustain livelihoods.

An outcome of community driven system dynamics is also our familiarity with all households in the community that has been very helpful in conducting monthly household surveys on changes in livelihood and forest resource use. Our participatory work has established us in the village as collaborators and partners not just working with FES but with the villagers to address issues of fuelwood availability in Sadhukonda Reserve Forest. A strong indicator of our trust and presence in the village is the full cooperation from households to provide monthly household data to help test our initial dynamic models.

As we approached the village to establish and validate a reference mode, villagers raised numerous questions about our motivations, the intent of modeling livelihood and forest interactions and the eventual outcome for them from our work. Merely explaining was not sufficient to allay their concerns about our real intent. We were able to overcome their doubts or reduce their level of concern by fully including them in the process of establishing a reference mode and model their livelihood strategies and use of local forests. Trust and our establishment in the village is a by-product or a positive externality of our inclusive modeling strategy where we consult and involve the community in developing reference modes, causal loop diagrams, and the final models. We are confident of being able to work with this village for some years to come. Our involvement of households and the community itself has helped in gathering monthly household data on livelihoods, income, expenditures, and forest use. It affirms our belief that involving people embedded in the dilemma gives us a better grasp of the dynamic problem, but significantly improves our ability to gather longitudinal data to build dynamic models of the problem at hand over time.

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