

Using **Spatial Information** to Understand Forest Change and Community Dynamics:

A Case From Nepal

by

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Abstract

The forest composition we witness today is a product of temporal anthropogenic and nonanthropogenic disturbances. Any investigation dedicated to understanding the impact of human activities on forest resources requires longitudinal information related to forest condition. Or does it? Scholars from geography, anthropology and other disciplines have long been aware of the informing nature of spatial relationships: human actions in a previous time often leave their imprints in today's landscape. Traditional empirical studies of forest condition typically ignore this type of information and rely on aggregated forest-level indicators developed from aspatial plot-level analyses. This paper conducts a spatial analysis of one forest product species in forests in a foraging setting in the Siwalik hills of Nepal. The forest species of particular importance to the surrounding communities for timber, fodder and fuelwood. Forest plot locations were accurately located using Differential Global Positioning Systems (DGPS) technology and were processed using an Arc-Info™ Geographic Information System (GIS). After accounting for the natural distribution of the species and other physiographic influences using maximum likelihood regression analysis, a pattern over the landscape is revealed. This pattern is not surprising for it accurately reflects what we would expect given the incentive structures, forest governance arrangements, village geography and community norms and dynamics in the area. This provides an example of how a spatial analysis of cross-sectional forest condition data can be used to extract information about forest change when longitudinal data are nonexistent.

KEY WORDS: forests; foraging; spatial statistics; institutions; Nepal

INTRODUCTION

Over the past decade, considerable attention has been given to the subject of human induced forest change and the depletion of particular species in forests (Myers, 1988; Aldhous, 1993; Repetto, 1988; Lovejoy, 1980; Task Force on Global Biodiversity, 1989; Norton, 1986; Reid and Miller, 1989). Often, these studies take a macro view of the problem, focusing on general political or economic influences (Repetto, 1988; Richards and Tucker, 1988). Other research shifts attention to the individual and searches for deeper understanding of influential variables that influence foraging behavior. Some of these "micro-scale analyses" focus on the influence of institutions or rules-in-use that create or modify human incentives and behavior related to forest product consumption (Ascher, 1995; Angelsen, 1995; McKean, 1992; Thomson, Feeny, and Oakerson, 1992; Ostrom and Wertime, 1995; Morrow and Hull, 1996).

Micro-level investigations concerned with understanding the human impacts on forest change require some capacity to quantify forest condition and some method to analyze change in that condition. The standard method of quantifying forest condition is to (1) take a sample of vegetation using a sampling strategy using forest plot measurements, (2) calculate species abundance indicators (e.g., species density, dominance or frequency) from these plots, and (3) use these indicators to describe the current status of the forested area as a whole. Plot-level analyses are also sometimes conducted (see for example, Umans, 1993), but usually without attention to the spatial distribution of the plots. If the researcher is *extremely* fortunate, prior data may have been collected on forest condition and these baseline data can be compared with newly

collected measurements. General conclusions can then be made regarding the change in forest resources and the impact of current institutional arrangements and forest policies on human foraging incentives in the region.

Unfortunately, it is rare to find a study location that actually has had a prior forest inventory conducted. In most cases, especially in developing world settings, we have information gaps: no prior data exists on the condition of a forest we set out to study. Understanding change in the resource in this context is quite difficult, for no baseline data exists for comparison. Even in the rare circumstance where a baseline dataset exists, it is either not georeferenced, or is georeferenced in an aggregated form. In such cases, we run into the "ecological inference" problem (King, 1997): we may know that change has occurred, but we may not know where the "hots spots" of change (e.g., deforestation fronts) are located.

So, how then do scholars and policy-makers who are interested in understanding the human dimensions of forest change overcome this problem? Scholars from geography, anthropology, and other disciplines have long been aware of the informative nature of spatial relationships: yesterday's human actions often leave imprints that remain apparent in the landscape of the natural resource of today (Pickett and CanDENASSO, 1995; Keller, et. al., 1996). In circumstances where we lack longitudinal data we can still extract new information related to change through the study of these patterns. Unfortunately, up until very recently, our ability to capture spatial relationships was hampered by our inability to collect accurate spatial data. However, the emergence of differential global positioning system (DGPS) technology provides new opportunities for the accurate georeferencing of data. Armed with this new information and the

digital processing capabilities supplied by geographic information systems (GIS) and spatial statistics, we can more easily collect accurate spatial data and analyze it for expected spatial patterns. Spatial analysis provides an opportunity to extract additional information about forest change in instances where no baseline forest condition data exist (Schweik, 1997).

Further, in addition to overcoming the "no baseline data" problem, spatial analysis at a forest plot level may help shed light into community dynamics—something that might be missed using data aggregated at the forest level. For example, in agrarian societies that depend on forest products for subsistence, the existing spatial distribution of an important forest product species may reflect human foraging decision making in response to the physical geography and established harvesting rules or social norms. Over geographic space, particular forest locations may be subject to heavier harvesting as foragers respond to constraints and opportunities posed by existing community relationships and forest-governing institutional structures. To the researcher or policy-maker interested in understanding how community inequities and governance arrangements influence the harvesting behavior of foragers, a spatial analysis could be quite revealing.

The primary goal of this paper is to develop a method that combines and takes advantage of technological and analytic advances—DGPS, GIS, institutional analysis and maximum likelihood regression—to tease out the human dimensions of forest change using a cross-sectional forest plot dataset. The paper is organized in the following manner. First, the study site and data collection methods are described. Second, more detail is provided on the setting, focusing in on the forest governance arrangements and human foraging patterns based on villager

accounts and what we observed in the field. Based on this knowledge of the foraging setting and institutional configurations, plausible geographic patterns in the distribution of a particularly important forest species are presented. Third, a brief, more traditional analysis of aggregate forest condition data is presented. Several issues are raised in regard to understanding forest change using these aggregated measures. The fourth section then turns to a more detailed spatial analysis of the data. The theoretical foundations and a "species density" forest plot model are established. This model contains a spatial component to capture the expected patterns in the data that are a result of past human foraging practices. The fifth section provides an overview of the statistical methods applied. Specifically, techniques used for identifying the natural, undisturbed spatial distribution of the species of interest and results from the statistical model are presented. Finally, a discussion of the results is presented and the paper concludes with reflections on some of the techniques used.

THE STUDY SITE AND DATA COLLECTION

In October 1994, forested areas within the Kayar Khola watershed in the Chitwan district of southern Nepal were chosen for study (Figure 1). The Siwalik hills of Nepal, especially in the district of Chitwan are under a tremendous amount of human pressure (see for example, Shrestha, Velu and Conway, 1993) and therefore were considered an appropriate location for research. The project, a part of the larger International Forestry Resources and Institutions (IFRI) research program at Indiana University, gathered information regarding forest governance, use, and condition along with socioeconomic attributes of villages that utilize these resources

(Ostrom and Wertime, 1995). A research team comprised of Nepali researchers¹ and the author spent six weeks living in the field learning from the villagers about their foraging practices and the institutions governing forest harvesting and management. The research area is located at the juncture of the Kayar and the Shaki river systems. Figure 2 presents a scanned and geometrically rectified 1995 topographic map of the region. This map was created by His Majesty's Government of Nepal (HMGN) through interpretation of 1992 aerial photographs of the region. Grey areas designate forests and white areas reflect either degraded forest or areas under some agricultural regime.

*** Figure 2 about here ***

Three general communities exist in the study area: Milan on the west bank of where the Shakti and Kayar rivers converge, Shaktikhor to the east along the banks of the Kayar, and Lataui to the north of Shaktikhor, up into the hills.² A fourth community, Chherwan, higher in the hills was not part of the IFRI study but discussions were held with villagers from there were made later during a subsequent field study.

In general, the villagers in the western village of Milan are relatively more well off than the other communities—many households own good land along the river with ample access to water

¹ The research team is part of the Nepal Forestry Resources and Institutions Consortium in Kathmandu, Nepal.

² The village names supplied by the people living in the area and recorded on the IFRI coding forms *differ* from the formal names identified on this map (see Table 1 for a comparison). To minimize reader confusion, the formal HMG map names will be used.

to irrigate rice fields. Milan also exhibits more heterogeneous population when compared with the other two eastern communities, with most members from the Chepang, Chettri and Newar ethnic groups but others such as Brahmin, Tamang, Gurung and Magar are also represented. The eastern villages of Latauli, Shaktikhor and Chherwan also are comprised of subsistence farmers living in areas where it is more difficult to irrigate given their topographic setting. Consequently they settle more often for other crops such as maize that require less water, are hardy and less commercially valuable.

The scanned topographic map provided by HMGN in Figure 2 is also helpful for it identifies household point locations within these villages. These point locations were also interpreted from the 1992 aerial photos and reflect fairly accurately what we observed in the field. In a few instances (especially in eastern hilly regions), additional household locations were digitized where they were not sufficiently represented on the HMG map so that the GIS most accurately reflects villager household estimates and configurations identified during the IFRI study. These estimates are presented in Table 1.

*** Table 1 about here ***

FORESTS, FOREST GOVERNANCE, USE AND POSSIBLE OUTCOMES

The majority of the villagers in each of these three communities are subsistence farmers and depend heavily on forest products for their livelihood. The term "forest," as defined by the

IFRI research program, is an area encompassed by some woody biomass, larger than .5 hectares in size, governed by a similar governance structure, and utilized by at least three households. Three forests, by this definition, exist at the study site: to the west, Sugabhanjyang forest; to the east, Latauli forest; and to the south, Kaswang forest (Figure 2). They all are semi-deciduous, climax *Shorea robusta* forests.

All three forests in the study area are designated official "government forests" and fall under the management of the District Forest Office (DFO). The DFO manages forests through Village Development Committee (VDC) boundaries which are the smallest political units in the Nepalese administration system. A VDC boundary runs directly up the Kayar river in the south west and then follows the Shakti river northward effectively placing the western Sugabhanjyang forest under a different VDC jurisdiction from that governing Kaswang and Latauli.

There are three formally established DFO rules related to forest product use. First, anyone who is a member of a VDC is permitted to harvest grass, tree fodder, and deadwood from forests within that VDC to fulfill their daily subsistence requirements. Second, live trees can only be felled if formal written permission is received from the DFO prior to harvesting. Third, a "no encroachment" rule exists that prohibits the conversion of DFO forest land to some other land use.

DFO guards stationed at VDC range posts are responsible for the enforcement of these rules. These DFO range post offices are a significant distance away from the forests: the range post responsible for the monitoring of Sugabhanjyang is located approximately 14 kilometers to

the southwest of Milan, and the DFO range post for Latauli and Kaswang is located approximately 16 kilometers southeast of the village of Latauli (both well off the map in Figure 2). At each range post, approximately 10 guards are stationed. These guards are responsible for patrolling—largely on foot—a hilly, almost mountainous area that extends over 100 square kilometers. Their task is daunting and their effectiveness appears to be quite limited. It is not surprising that their efforts, while weak everywhere, appear to be a bit more effective in geographic locations more easily accessible from their range post locations. Villagers report relatively few interactions with forest guards, but when they do occur they tend to be more frequent in areas along the motorable road through Milan on the southwest side of Figure 2. At one point during our field work, the research team witnessed the enforcement of the no-encroachment rule. DFO guards destroyed the home of a person who encroached upon land in the southwestern tip of the Sugabhanjyang forest. The guards then hauled the building material away on a truck. This incident, while reportedly rare, proves that there is limited rule enforcement by the DFO in areas reasonably close to the motorable road through Milan.

The map in Figure 2 shows the road crossing the Shakti river and going through the eastern village of Shaktikhor. This map is misleading, for crossing this river in a vehicle at any time of the year is quite difficult. The convergence of the two rivers at this junction leads to a process called "the backwater effect" (Bruijnzeel and Bremmer, 1989: 64) where tremendous quantities of boulders and rocks are deposited in the Shakti river bed. Motorable crossing here is very difficult even in the dry season. The result, confirmed by villager reports, is that the monitoring of the Latauli and Kaswang forests by DFO guards is much less frequent than is found in Sugabhanjyang.

Forest use by all villagers in all communities appears to be very much the same. Villagers harvest timber for construction and for tools; fodder, leaf litter and grasses for livestock and other agriculture purposes; and fuelwood for cooking and heating purposes. We witnessed these types of foraging activities during our weeks in the field. People from all villages reported that two major human activities are causing what they deem as a rapid depletion of their forest resources. The first, is forest conversion to agriculture. The second is forest product extraction: the harvesting of timber, fuelwood, and tree fodder (lopping). Tree lopping is especially prevalent, which, as Metz (1990: 285) notes, significantly reduces the opportunity for species to regenerate.

While the formal DFO rules appear to be well understood, in many respects they are not followed: what we observed in the field proved that these rules were always being broken. The slash and burning of forest land for agriculture perhaps is the most extreme DFO rule violation and this practice is prevalent especially in higher locations in the hills. This aspect of the human-forest dynamics is described in much more detail in Schweik, Adhikari and Pandit (1997). However, foraging-related violations also occur frequently. The villagers from Milan, more wealthier (relatively) and ethnically diverse, report that they harvest not only from the Sugabhanjyang forest in their VDC, but they also lop trees for fodder and gather grasses from the eastern Latauli forest in the neighboring VDC. This is a direct violation of the DFO established rules in the area. Interestingly, the villagers from the western communities of Shaktikor and Latauli don't seem to mind. No complaints have been registered to the DFO range post. Even more puzzling, the villagers from the western communities of Shaktikhor, and Latauli, on the other hand, report that they forage in the Latauli forest only. They explain that most of the year the Kair river flows too wide for them to access the Kaswang forest to the south, and that no

consideration is even given to harvesting in the Sugabhanjyang forest in the neighboring VDC. Research team members who lived in the villages, held numerous discussions with villagers about foraging behavior, and monitored forest harvesting activities for nearly six weeks, confirm this behavior (Shrestha, 1996). Each side adapts a "that's just the way it is" type of attitude when asked about these foraging patterns. It appears, then, that an unwritten social norm exists across communities that effectively permits western (Milan) villager foraging in the eastern Latauli forest but doesn't allow the converse to occur. Some of this may be due to ethnic hierarchies, and some of it may be because some villagers in Shaktikhor work for people in Milan in their agriculture fields. This community dynamic adds additional foraging pressure—particularly lopping pressure—on the Latauli forest, a forest already heavily used by the Shaktikhor, Latauli and Chherwan villagers.

Anticipated Patterns in Forest Vegetation

From the previous discussion, we are now in a position to develop hypotheses related to forest vegetation patterns given what we know about the forest governance structure and monitoring capacity, forest product uses, geographic locations of households, and community relationships. In this setting, one of three patterns of vegetation over the landscape are likely.

Pattern 1: No Human Influence

The first possible pattern is one of a "naturally" distributed forest ecosystem where human activity is so minimal that the forests are able to replenish at a rate faster or equal to what is being removed. The pattern of vegetation in any forest, then, would be no different than what

would be found in a comparable forest in a similar ecological setting that has not been influenced by human harvesting. Each particular species follows its own "naturally induced" distribution over the topography. The graphic in Figure 3 a describes this landscape. The likelihood that this type of pattern exists in Sugabhanjyang or Latauli is doubtful, however, given that villagers from all communities report that these two forests have been significantly degraded over the past 20 years.

*** Figure 3a, 3b and 3c about here ***

Pattern 2: Open Access and Optimal Foraging

The second pattern that might be identified in forest vegetation is one that reflects an "institutionally-free" open access situation where human decision-making and harvesting is driven simply by optimal foraging strategies. Optimal foraging theory depicts human foragers as actors who maximize their net rate of return of energy per unit of foraging time (Smith, 1983). While a number of alternative theories on foraging decision making exist (see Smith, 1983: 627), they all characterize the forager as a person who strives to minimize his or her search time and effort (Hayden, 1981; Winterhalder, 1993). If humans harvest a particular species at a rate higher than can be regenerated by the forest, optimal foraging would predict that fewer important product species will be found in locations easily accessed by humans (e.g., a short distance away from the village, near a path, or at a lower elevation).

In the context of this site, we would expect important product species to be higher in number in areas further away from villages and at higher altitudes where it is more difficult to

walk. Alternatively, the density of important product species would be lower in areas that are proximate to household locations. Consequently, we would expect Kaswang to exhibit a high degree of "naturally induced" species distribution, given that it is well protected from foraging by the river systems and few human settlements exist within or near it. We'd also expect the northern part of Sugabhanjyang to exhibit a relatively "natural" condition, given that it is high up in the hills and no villages exist to the north. Alternatively, we'd expect the southern half of the Sugabhanjyang forest near Milan to be relatively hard-hit in terms of foraging pressure, as well as on the eastern side of Latauli where the forest is completely surrounded by settlements. Finally, given population locations, optimal foraging would predict that the forest most affected would be the western side of Latauli—the part in the center of the map that sits in between Milan, Shaktikhor and the upland village of Latauli. Figure 3b depicts this optimal foraging induced landscape.

Pattern 3: Optimal Foraging Combined with Institutional Influences

Smith (1983) reports that empirical studies testing optimal foraging theory have revealed that in some instances human foragers are selective in their utilization of available resources. Other studies have revealed foragers who exhibit much less concern. Smith also states that there is little agreement in the anthropological community over these foraging differences (1983: 628-29). While not stated specifically, Smith's discussion alludes to the importance of community relationships and the important role institutional arrangements play in altering human foraging patterns and in the preservation of natural resources.³

³ For example, Smith (1983: 632) describes the role that "exclusive control" plays in the conservation of natural resources. Feit (1973) describes rotational hunting by the Waswanipi Cree people as a method in which the size of animal population can be controlled.

Ostrom (1990) extends Smith's argument by emphasizing the role institutional arrangements play in altering the incentives humans face in their decision-making context. Institutions in this context refer to the property rights and rules-in-use that govern the harvesting of a particular species or of particular areas (what we might refer to as management units) within a forest. The institutional composition in this setting is such that the forests are, to a significant degree, open access. The expectation is that optimal foraging patterns will prevail. But, the possibility exists that foraging decision-making over the years may have been altered by what I have referred to as the past and present "institutional landscape" configurations (Schweik, 1997). The institutional landscapes in this setting, albeit weak (see Schweik, Adhikari and Pandit, 1997, for more detail), still may have altered human foraging behavior to some limited degree. If this is the case, the vegetation pattern across the landscape would reflect a new optimal foraging cost-benefit calculus, where the decision to harvest or not to harvest at a particular location includes a consideration of rules, rule penalties and the likelihood of getting caught breaking a rule (Ostrom, 1990, 1997).

In the site description presented earlier, there exist two primary institutions that appear to be somewhat influential in driving human decision-making away from what optimal foraging might predict: the monitoring practices along the road in Milan and the established social norms that exist between the Milan and Shaktikhor communities. In this case, DFO monitoring appears to be relatively ineffective, with the possible exception of forested areas adjacent to the road through Milan. This more active forest monitoring by DFO guards in the west could supply an incentive for the Milan villagers to harvest up into higher regions of Sugabhanjyang and across the river into Latauli *in locations that are not visible from the road*. This, in conjunction with the

interesting social dynamic we observed—the unwritten or accepted rule which allows villagers of Milan to harvest in the Latauli forest but not vice versa—places added pressure on the eastern side of the Latauli forest. Thus, in a setting where both optimal foraging and these institutionally induced incentives are present, we'd expect a landscape that reflects more of a continuous loss of species individuals in the forest—a species depletion trend—as one moves from the west to east (Figure 3c).

TRADITIONAL METHODS OF FOREST CONDITION ANALYSIS AND THEIR LIMITATIONS IN ASCERTAINING FOREST CHANGE

With the situation described, let us first undertake the more traditional "aggregated" analysis of forest condition to see if there is evidence to support either of the three possible patterns.

Forest Plot Data Collection

Our IFRI study utilized a traditional forest plot sampling to measure condition for each of the three forests identified. The team included one forester, one botanist and several assistants, and utilized ten-meter radius circular forest plots for sampling. Due to the steep terrain within these forests, the team followed trails to reach fifty-meter altitudinal intervals. At each location, a random number was used to determine the direction and the distance from the trail that the corresponding plot should be taken. Overall, 97 forest plots were sampled (Figure 2). Data recorded include:

- soil characteristics, such as the depth of the humus layer, and the depth and color of the "a" and "b" horizons;
- tree identification, including diameter at breast height, height and species type for each tree within the plot;
- sapling and shrub information;
- plot physiographic information, such as slope (in degrees), elevation (using an altimeter) and aspect (the direction the slope faces);
- ancillary observations, such as the existence of insect damage, signs of animal grazing, and evidence of human harvesting.

We also did something rather unusual—but soon to become more prevalent. We were fortunate to have two eight-channel GPS receivers and a laptop computer with us in the field. This allowed us to collect accurate positional data regarding these forest plots. It is generally agreed that a single GPS unit working alone in the field is capable of providing location coordinates (e.g., longitude/latitude or UTM projection) accurate to approximately 100 meters (Pace *et al.*, 1995; August *et al.*, 1994). For any analysis conducted at a forest-plot level, 100 meter error (radius) is too great. Plot positions would be erroneous using a one-GPS receiver technique. However, using two receivers together—a technique which employs one GPS machine with a laptop computer as a "basestation" at a known location, and the other GPS collecting data in the field—can improve positional accuracy to about 1-5 meters (Pace, et al, 1995). The process, referred to as "post-processing differential correction," is explained in detail by Pace et al. (1995) and on a variety of GPS related internet sites. Using differential GPS techniques, we were able to collect accurate forest plot positions in longitude, latitude and UTM coordinate systems. These positions were then converted to a GIS point coverage and are overlaid on the georeferenced map presented in Figure 2.

A Focus on Important Product Species

If we are interested in understanding deforestation practices in a foraging community, it is most helpful to focus analysis on the species the communities find important. My point here is simple: in any setting where foraging levels are high, the severity of the deforestation will manifest itself *first* in the distribution (or lack thereof) of the species that contributes the most to villagers' daily subsistence requirements. The villagers in all communities mentioned the same five tree species as the ones most useful in supplying their timber, fodder and fuel wood needs. The most important one is *Shorea robusta* (referred to as "Sal" locally). Four other species were also mentioned as highly valuable: *Nyctanthes arbortristis* (Parijat), *Adina cordifolia* (Karma), *Lagerstroemia parviflora* (Botdhainyero), and *Terminalia tomentosa* (Saj).

An Aggregate Forest Plot Analysis

A comparison of the mean diameter at breast height (DBH) and the mean height of each of these species for each forest are presented in Figures 4 and 5. While there is some fluctuation in mean DBH between forests for particular species, nothing strikingly different is identified in this comparison.

*** Figures 4-9 about here ***

Figures 6, 7, 8 and 9 provide a comparison of absolute density, frequency and dominance and species importance values of these species across the three forests. Density (Figure 6)

provides a measure of the number of species present in a forest. It is determined by counting the number of individual species and then dividing this by the total area sampled. Frequency (Figure 7) provides a measure of how widely a species is distributed within a forested area. It is calculated by taking the number of plots in which a species occurs and dividing this by the number of plots sampled. Dominance (Figure 8) provides a measure of the standing biomass a particular species contributes to a forest composition. Dominance is calculated by taking the total basal area of a species and dividing it by the area sampled. Finally, the importance values (Figure 9) of each species reports the sum of the *relative* density, dominance and frequency together divided by three. These aggregate measures are commonly used when comparing the conditions of different forested areas.

These figures provide strikingly hard evidence to support villager concerns of forest species depletion in the Sugabhanjyang and Latauli forests. The Kaswang forest—the relatively untouched forest—is quite different from the other two. In the density, dominance, frequency and importance value charts, Kaswang reflects a very different composition with a much higher presence of the important product tree species *Shorea robusta* something we would expect in a *Shorea robusta* climax forest.

But beyond the striking evidence produced from a comparison of Kaswang to Latauli and to Sugabhanjyang, it becomes less clear from this cross-sectional aggregate data how the forest landscape has been transformed by human activity. It is clear that Sugabhanjyang and Latauli are comprised of differing levels of vegetation than is Kaswang, but we cannot easily identify whether Latauli or Sugabhanjyang follow patterns of optimal foraging in Figure 3b or optimal

foraging coupled with institutional influences in Figure 3 c. In fact, the lower measures found in Latauli and Sugabhanjyang could also be a result of purely natural forces: the topography or soil conditions could be less hospitable to these species in Latauli than in Sugabhanjyang. It could be that Latauli *always* exhibited fewer *Shorea robusta* individuals than its neighboring forests. We simply can't make any strong statements about forest change from these aggregated data alone.

USING GEOGRAPHIC RELATIONSHIPS TO UNDERSTAND CHANGE: A SPATIALLY EXPLICIT "SPECIES DENSITY" MODEL

The argument made earlier is that by giving some extra consideration to spatial relationships and testing for these factors we can improve our understanding of forest change in instances when baseline forest condition data is unavailable. The intention of the rest of this paper is to develop a spatially explicit model that captures the influence of the foraging dynamics as reported by villagers. Multivariate regression will be used to test this model. But before proceeding to the statistical methods and results, a brief theoretical discussion of important variables for the model is provided, along with the methods used to operationalize these variables. Figure 10 summarizes the model as outlined in this section.

*** Figure 10 about here ***

The Dependent Variable: A Measure of Species Density or Abundance

A spatial analysis requires forest plots to be the unit of analysis rather than aggregate forest measures. I have argued earlier that it is helpful to focus on one important forest product species

in this analysis. If we are concerned about the overharvesting of this species, we should work to explain the presence or absence of this species in a forest plot. Given that *Shorea robusta* is deemed so valuable and important to the villagers in these communities, a count of the number of these trees in a plot provides a simple but useful measure of species abundance.

The Independent Variables: Factors that Influence Where *Shorea robusta* Exists

Many factors determine whether a species is found in a particular plot. These influential factors can be divided into abiotic stresses, biotic stresses, and human stresses.⁴

Abiotic stresses

Each forest plot has physiographic characteristics that influence the capacity for a particular species to grow in its environment. These characteristics include slope, aspect (or slope orientation), elevation, and soil type and condition. These attributes can play a tremendous role in the number and type of species that exist within a plot. Variation in the topography and soil provide specialized environments that encourage or discourage particular species to grow (Spurr and Barnes, 1992). Slope steepness and aspect are two crucial factors that determine whether a particular species will survive within a given forest plot. These variables dramatically influence the micro-ecosystem characteristics—exposure to sunlight, rainfall, and so on—that exist within the plot. Any model that attempts to explain human impacts on a forest environment must control for these features. The field team recorded slope steepness in degrees with a clinometer.

⁴Human stresses could be considered biotic variables (e.g., see Kozłowski, Kraemer, and Pallardy, 1991), but because of the importance of the human pressures in this study, I treat it as a separate category.

A review of the topographic map provided in Figure 2 reveals the hilly nature of this environment. We would expect then, that the steeper a slope is, the more difficult it would be for a *Shorea robusta* tree to establish sound root systems. Slope aspect captures the direction a slope faces. In the field, the general aspect of the plot was noted. Aspect is operationalized here as a categorical variable: a zero represents a north-facing slope; a one represents either a northwest or northeast facing slope; a two represents an east or west facing slope; a three represents a southwest or southeast facing slope and a four represents a completely south facing slope. It is not clear what effect, if any, aspect will have in this area. Given that the Nepal Terai is located in a subtropical region, all slope types may receive generally comparable levels of sunlight over a one-day period. I include aspect in the model to capture any influences it may have.

Soil nutrients, moisture, and physical composition are also highly influential factors in the growth and survival of particular species. Three soil horizon depths are typically reported in soil analysis: the "O" horizon (humus or ground litter layer), the "A" horizon (a darker mineral layer at the top of the soil), and the "B" horizon (the soil deeper in the ground). The color of these layers as well as textures (sandy, loamy or clayey) are also important determinants in what species can grow in the area. A soil analysis was performed on each forest plot which includes depth, color, and texture of these horizons (IFRI, 1994). These soil measurements are included in the model to capture any influence they may have on the presence of *Shorea robusta* trees.

Other natural disturbances also influence what grows in a particular area. A plot area may be subject to severe weather damage caused by a lightning strike or a fallen tree. This damage results in renewed competition by the vegetation that survived. The IFRI forms record

observations for each plot on natural disturbances, but there were no major evidence of weather related disturbances identified in or around forest plot locations.

Biotic Stresses

The number of a particular species within a plot is also influenced by a variety of biotic environmental stresses. The existence of competitor tree species in a forest plot are highly influential in determining whether another species can survive in that particular location. Competition for light, moisture, and nutrients exists in every plot, and species that can better tolerate the plot's conditions with respect to other species will have a better opportunity to grow. Since all trees in each plot were identified, measured, and entered into the IFRI database, this analysis uses a measure of competing tree biomass—a summation of the diameter at breast height (DBH) for species other than *Shorea robusta*—to capture the influence of rival species within each plot. We would expect that the more competitor species there are in a plot, the less likely *Shorea robusta* species will be found.

The proximity of neighboring *Shorea robusta* seed trees often determine if a tree will grow in a particular plot. The type of seed and its transportation medium influence where it may grow. The seed of a *Shorea robusta* is a samara⁵ and may be carried a great distance by wind disturbances (Storrs and Storrs, 1990). Given that these seeds can potentially travel great distances, and that these forests are all *Shorea robusta* climax forests stocked even now with *Shorea robusta* species (see Figures 4-9), it is safe to assume that each forest plot has an equal likelihood of having *Shorea robusta* seed trees somewhere in its vicinity.

⁵ A winged seed.

Animal grazing activity also influences species survival within a plot. Animals forage for particularly tasty or nutritious species and these grazing habits often then determine the fate of many seedlings. In contrast, species not particularly interesting to animals may continue to survive or even thrive. However, the grazing of livestock is closely related to the location of households and therefore that influence will be captured through a variable related to human activities discussed below.

Human Stresses—foraging pressures

Now we turn to the problem of how to best operationalize human foraging pressures for this model. Given our understanding of the geographic, topographic and institutional composition of the setting, we can attempt to establish some "plot accessibility" measure that would capture the influence both of optimal foraging and of institutional influences on human harvest decision-making. Ideally, some measure of effort or cost could be quantified for each plot that accounts for both optimal foraging decision-making and also the effects of institutional arrangements and monitoring/sanctioning mechanisms. Four methods were considered, and two were actually applied.

The first method considered to capture optimal foraging was to calculate the distance from each plot to the center of a village or villages. This is a simple measure to calculate using a GIS, but it is difficult in this circumstance to identify just what exactly is "the village." A glance at the household configurations for the villages in Figure 2 proves this point. Households in each community are scattered throughout the landscape. There is no easy (or useful) method of determining a distance to plot from a village centroid. This approach was rejected.

The second method would be to somehow measure the distance of each plot from trails within the forest. Once again, with trails digitized in a GIS system this is a fairly straightforward task. However, two reasons make this approach impractical. First, the trails on the current map do not accurately reflect what we know to exist in the field. The map in Figure 2 shows only a few trails, yet, we know that in Sugabhanjyang and Latauli, there are elaborate series of trails criss-crossing throughout each forest. We could attempt to digitize trail locations based on our knowledge and hand drawn maps of the area, but the error in placing these trails would be high enough that using distance to plot as a measure would lead to possibly erroneous results. For this reason this approach was also rejected.

The third method considered to quantify optimal foraging pressure was to develop (1) a count of the number of households within a certain distance from each plot and (2) a measure of the distance all these households are from the plot. This approach was used, Figure 11 provides an example of how this measure was calculated for three forest plots. Using the GIS household coverage, the Arc-Info™ GIS "pointdistance" function could be utilized to calculate the distances between one GIS point layer (forest plots) and another point layer (households) within a 1-kilometer search radius. While in some instances foragers may go beyond one kilometer to forage, this distance assumption is reasonable given what villagers have told us and given the hilly terrain these people actively forage. From the output provided by the pointdistance function, distance measures for all households within this radius to each plot and household counts could be easily quantified. We would expect that plots would have less *Shorea robusta* trees if there are a larger number of households within a kilometer. We would also expect that the closer these households are to the plot the less trees these plots would have on them. One

limitation of this method of quantifying foraging pressures is that it does not take into account the institutional attributes governing the areas within which the forest plots fall.

The fourth method considered in the development of a plot accessibility measure tries to account for both the optimal foraging dynamics and the institutional setting of the area. This took some hard thinking about the dynamics of the foraging setting using Figure 2, and tries to capture the pattern described earlier in Figure 3c. Given that the Sugabhanjyang and the Latauli forests lie generally in a west-east relationship, the possibility exists that the optimal foraging patterns coupled with the existing institutional configurations produce a forested landscape that is more depleted as one moves from west to east. In the past, geographers have applied coordinate systems as independent variables—what is commonly referred to as trend surface models—to capture the influence of trend across a landscape. For this reason, the use of DGPS produced X and Y coordinates were added to the model to capture these institutionally induced foraging dynamics.

STATISTICAL METHODS AND RESULTS

In this section, multiple regression estimation is applied to the model shown in Figure 10. Traditional Ordinary Least Squares (OLS) regression assumes the underlying distribution of the dependent variable to be a normal, bell-shaped curve. The dependent variable—the number of *Shorea robusta* species in a plot—is an event-count variable.⁶ Long (1997) notes that count

⁶ For a discussion of maximum likelihood event count models, see King (1989) or Long (1997).

variables are often treated as continuous and the linear regression model is applied. This leads to estimates that are inefficient, inconsistent and biased. Further, Ludwig and Reynolds (1988) state that a normal distribution assumption is often not correct when counts of biological phenomena are utilized. King (1989) argues that maximum likelihood estimation (MLE) is a better approach, for it allows the researcher to specify both the distribution of the dependent variable and the relationship that independent variables have with the dependent variable (referred to as the "functional form" of the model).⁷

MLE assumption 1:

Identification of the natural distribution of the *Shorea robusta* species using a reference forest

The first assumption required for MLE is the identification of the most theoretically appropriate distribution of the dependent variable. This distributional flexibility of MLE avoids residual violation problems that traditional OLS estimation encounters. MLE requires the identification of the distribution of this event-count variable, and our investigation requires that the distribution be in a setting that is relatively undisturbed by human activities.

Counts of biological species usually follow one of three types of spatial arrangements: random, clustered, or uniform (Ludwig and Reynolds, 1988). In the case of a random dispersal

⁷ King (1990) also argues that with the computational power available in today's personal computers, researchers should now move to more sophisticated regression models that are more true to our theoretical understanding of the real world instead of using traditional techniques that were developed for computational simplicity. In addition, models that violate the OLS assumption of normality force the researcher to implement statistical tricks to ensure that the residuals behave properly. This research avoids having to use statistical tricks by investigating and specifying the correct distributional assumption and then modeling it using MLE.

of species, each plot has an equal chance of hosting a *Shorea robusta* individual, resulting in a frequency distribution that is normally distributed (centered around the mean). In such random patterns, the variance will be very close to the mean in value. The second pattern, a clustered pattern, is commonly found in biological studies and follows a negative binomial distribution. Clustering will result in a large number of plots where no *Shorea robusta* individuals are identified. The variance in a clustering pattern will be greater than the mean. Finally, the third pattern often identified is a uniform pattern where almost every plot exhibits the same number of *Shorea robusta* individuals. In these spatial patterns, the variance will be less than the mean (Ludwig and Reynolds, 1988).

A "reference forest" is required to identify the natural distribution of the *Shorea robusta* species.⁸ A reference forest is a forest that provides an adequate representation of what the other forests would be like if undisturbed by human activity. Given what we know about the Kaswang forest, this condition is satisfied. First, it is an adequate representation of the other two forests for because the Nepali foresters in the field identified all three as *Shorea robusta* climax forests. While each forest exhibits generally different slope aspects, given that this region of the earth is subtropical, it is safe to assume that each forest receives comparable amounts of sunlight exposure during the day. Second, given Kaswang's natural protection from human harvesting due to the river systems, it appears to be the forest that exhibits the least exposure to human foraging. The aggregate measures in Figures 4-9 confirm this. For these reasons, I utilize the 31 forest plots sampled in the Kaswang Forest *separately* as the reference forest to determine a

⁸ Literature describing the natural distribution of the *Shorea robusta* species was not available.

natural distribution of *Shorea robusta*. The multiple regression model then utilizes the forest plot data from the Sugabhanjyang and Latauli forests only.

The variance-to-mean ratio or index of dispersion test (Ludwig and Reynolds, 1988) identifies the natural distribution of the *Shorea robusta* count for the Kaswang Forest (Table 2). The value for the Chi-squared statistic (df 30) is larger than the critical value at the .01 probability level, implying that *Shorea robusta* in natural settings follows a clumped pattern (variance is greater than the mean).⁹ This suggests that the dependent variable, the number of *Shorea robusta* species per plot, follows a negative binomial distribution in an undisturbed setting (Ludwig and Reynolds, 1988: 24). Therefore, a negative binomial is the appropriate distributional assumption for maximum likelihood estimation for this analysis.

*** Table 2 about here ***

MLE Assumption 2: Identifying the Model's Correct Functional Form

The second assumption MLE requires is the specification of the model's functional form. This requires the researcher to specify relationships (e.g., linear or nonlinear) between the dependent variable and each independent variable. An assumption of strict linearity is

⁹ Long (1997:221) summarizes this nicely in his discussion of Poisson regression models. "With this [Poisson] model the probability of a count is determined by a Poisson distribution, where the mean of the distribution is a function of the independent variables. This model has the defining characteristic that the conditional mean of the outcome is equal to the conditional variance. In practice, the conditional variance often exceeds the conditional mean. Dealing with this problem often leads to the negative binomial regression model which allows the variance to exceed the mean."

reasonable for specifying the relationships in Figure 10. There is no theoretical justification for the inclusion of exponential components. With the two assumptions for MLE regression specified, a negative binomial maximum likelihood was estimated.

Statistical Results

The results of the maximum likelihood estimation are presented in Table 3. Caution is required when interpreting the regression coefficients. Since they are a result of a negative binomial multivariate regression, they cannot be interpreted in the same manner as coefficients would be if they were produced by an OLS regression. One of the most intuitive ways of interpreting these results is by creating the incident rate ratio (IRR). IRRs can be easily interpreted as a percentage of growth or decline in the dependent variable due to a one-unit change in the independent variable, holding all else constant.

*** Table 3 about here ***

The steepness of the slope is found to have a negative influence on the existence of *Shorea robusta* species. The IRR can be interpreted as follows: holding everything else constant, a one-degree increase in the steepness of the plot will result in a 2.4 ($100 \times [1 - \text{IRR}]$ or $100 \times [1 - .9764]$) percent decrease in the number of *Shorea robusta* trees. The expected relationship holds, and it is not surprising that this parameter is not statistically significant. Treks through these forests revealed very steep slopes exhibiting an abundance of vegetation. During the field visit,

many species, *Shorea robusta* being one, appeared to be quite capable of establishing a foundation regardless of the steepness of the slope in these hilly areas of Nepal.

Similarly, slope aspect—measured as the degree to which the slope points to the south—is also not statistically significant. This is not unexpected. We witnessed *Shorea robusta* on all types of terrain facing all types of directions. It appears quite capable of growing in this environment regardless of the degree to which it receives sunlight.

Slope elevation has a positive relationship with the number of *Shorea robusta* trees in a plot and is statistically significant at the 95 percent level of confidence. For every one meter increase in elevation, the expected number of *Shorea robusta* trees will increase by .3 percent. This is a bit surprising, but not unexpected. Given that *Shorea robusta* can live in altitudes up to 1200 meters, and the highest plot taken in our sample is 830 meters, it is surprising that elevation has an effect at all. However, elevation captures two influences together. First, it captures the natural influence of elevation on the presence or absence of Sal trees—which in this case is theoretically quite limited. Second, it captures an aspect of optimal foraging: a degree of effort by foragers. Figure 2 shows that a majority of the people in this study site live in the lowlands near the river bed. I suspect that the positive influence of elevation is largely a result of foraging efforts and not as much effects of topography. As optimal foraging would predict, and as the villagers acknowledge, people tend to not want to trek from the river bed to high altitude locations to forage if they can help it. In this instance, patterns of optimal foraging are confirmed.

None of the soil variables were found to have any statistically significant explanatory relationship with the existence of *Shorea robusta* trees. This may reflect some problem in the soil data collected in this site. The soil analysis was conducted without a soil color chart. While the same people collected all of the soil data, the ability to discern soil color or texture accurately may have been lacking. The other possibility is that these variables are not influential because *Shorea robusta* is in fact the climax species of these forests: it may be robust in terms of its ability to grow in a variety of soils.

The existence of competing tree biomass is negatively related to the existence of *Shorea robusta* trees in the plot and is found to be highly significant. The coefficient, quite small, is deceiving. Its smallness reflects the measure used for competing biomass—the sum of the competing tree DBH in centimeters. A one-centimeter increase in competing tree DBH results in a less than one percent decline (-.45%) in the number of *Shorea robusta* species. The relationship makes intuitive sense and is what we expect: the existence of large competing trees in a micro eco-system will produce an area not receptive to *Shorea robusta* growth.

Neither of the 1 kilometer buffer variables used to quantify optimal foraging—(1) the number of households 1 kilometer from the plot and (2) the total distance of all the households within this buffer area—were found to be statistically significant. Given our knowledge of the site, this isn't surprising. These measures are inadequate in capturing the dynamics of the optimal foraging setting. First, a straight-line 1 kilometer distance doesn't adequately capture how far villagers often forage. Villagers report traveling much farther. In the dilemma over how best to operationalize this variable, a larger buffer (2 km) was considered, but if it were used

nearly every household in the area would be included in the count and distance for each plot. That measure would have been useful from a statistical point of view.

Second, and more importantly, a simple straight line distance doesn't adequately capture the human foraging decision-making in this situation. An improved method is needed to capture the distance of households from the plot using information related to trail locations. However the trail locations on the map in Figure 2 are insufficient and incomplete. Using DGPS to map trails would be helpful but time-consuming. Third, there is the possibility that other parameters may be affecting foraging decisions more strongly than the distance. This brings us to the trend component of the model.

The trend component of the model was included to capture both the influence of optimal foraging pressures and the institutional influences that alter human harvesting activity. Of the two trend parameters in the model, the X and Y GIS coordinates, the X was found to be significant at the 95 percent confidence level. The interpretation of this IRR for this variable requires a review of Figure 2. All GIS coverages are in a Universal Transverse Mercator (UTM) coordinate system. The X and Y coordinates reflect locations on this map. The Y coordinates follow the north-south axis, and the X coordinates follow the east-west axis. The origin is located in the center of the map—somewhere near the point where the Shakti and the Kayar rivers converge. The negative sign on the X coefficient suggests that as we move in an easterly direction, the number of *Shorea robusta* individuals decline. We can interpret the coefficient as follows: holding all else constant, a one unit shift to the east produces a .07 percent decline in the expected number of *Shorea robusta* trees found in a plot. As one moves across the map from

west to east, the number of *Shorea robusta* trees found in plots gradually decrease. This finding provides strong evidence of the optimal-foraging and institutional induced pattern shown in Figure 3c.

DISCUSSION

The results presented above have both substantive and methodological implications.

Substantive findings

Earlier in this paper—in the section labeled "Forests, Forest Governance, Use And Possible Outcomes"—expected forest patterns as a result of human optimal foraging and institutional induced pressures were presented. In general, it was expected that, given the forest governance structure, coupled with patterns of settlement and "natural" factors (e.g., locations of rivers) the three forests would exhibit different degrees of forest change in response to human activity over the years.

Given this, it was first hypothesized that the Kaswang forest, naturally protected by the river systems from human activities, would be the least affected by human activity. The aggregate plot data on forest species provides evidence confirming this hypothesis. Kaswang was therefore used as a reference forest and removed from the rest of the study in terms of an analysis of landscape patterns.

Second, it was hypothesized that optimal foraging coupled with limited pressures related to a weak "institutional landscape" in the area could lead to one of three possible patterns depicted in Figures 3 a, b and c. The statistical results lend support to the third scenario. After accounting for the influence of natural forces (e.g., topography), and trying to develop well-quantified measures that capture the influence of optimal foraging using household counts and location data, a strong decreasing trend to the east was still discovered. This trend suggests that the heaviest human pressures are in the far east and northeast sections of the Latauli forest. The statistical significance of the X coordinate in the model can be explained, to some degree, by optimal foraging and the pattern of households clustering around Latauli. But close examination of the arrangement of the population over geographic space does not explain why the trend continues to the farthest points east.

Given that soil characteristics appear to have little effect in the model and that other natural environmental influences are accounted for, the only other explanation for this trend is that human foraging decisions are based on a combination of optimal foraging and institutional structure in the region. The social norms allowing villagers from Milan to harvest Latauli and the more active monitoring in the west, drive humans to forage in patterns that are different from what we would expect from optimal foraging alone. Institutional configurations alter patterns of human behavior over geographic space. This conclusion is supported by what we witnessed in the field and what villagers reported (Shrestha, 1996): many Milan and Shaktikhor residents forage in this eastern side of the Latauli forest.

Methodological implications

While ecologists and biologists have made tremendous advances in the study of the spatial distribution of various plant species, to my knowledge, this is the first analysis of its kind that applies recent technological advances of DGPS, GIS, and maximum likelihood estimation to this effort. This study provides an example of how the inclusion of spatial information in a regression model may assist in understanding the human dimensions of forest change when longitudinal data is nonexistent. The findings support the earlier claim that a plot level of analysis may reveal findings that would not be discovered at the forest level of analysis.

Moreover, this study may also be the first of its kind to apply an institutional analysis to the study of the distribution of a particular species over geographic space. It provides a new technique for researchers to identify the influence of institutions on human foraging behavior. In any foraging setting, the first signs of forest depletion will be changes in the geographic pattern of particularly important product species as humans base their decisions and actions on the attributes of the physiographic, institutional, and community norms related to use of that forested area. After taking into consideration the natural distribution of a particular species, and accounting for physiographic influences that encourage or discourage growth, the analyst can study the existing pattern to reveal human response to past and present institutional arrangements. In this case, such an analysis provides evidence that monitoring and social norms produce shifts in foraging patterns away from traditional optimal foraging. Such evidence could not be discovered with an analysis of aggregated cross-sectional forest condition data.

Finally, it should be noted that this spatial analysis of "plots" is not limited to the study of forest natural resources. Similar techniques can be employed to study the association between natural resource condition and institutional design in other natural resource settings. In future work, for example, I intend to apply a similar technique to the study of farmer-managed irrigation resources in the same region of Nepal. Techniques such as this, can help us not only understand resource change, but also understand how institutional configurations exist over geographic space; perhaps, shedding some light into how effective institutional forms spread across a landscape or region.

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Figure 1: Study Site Location within Nepal

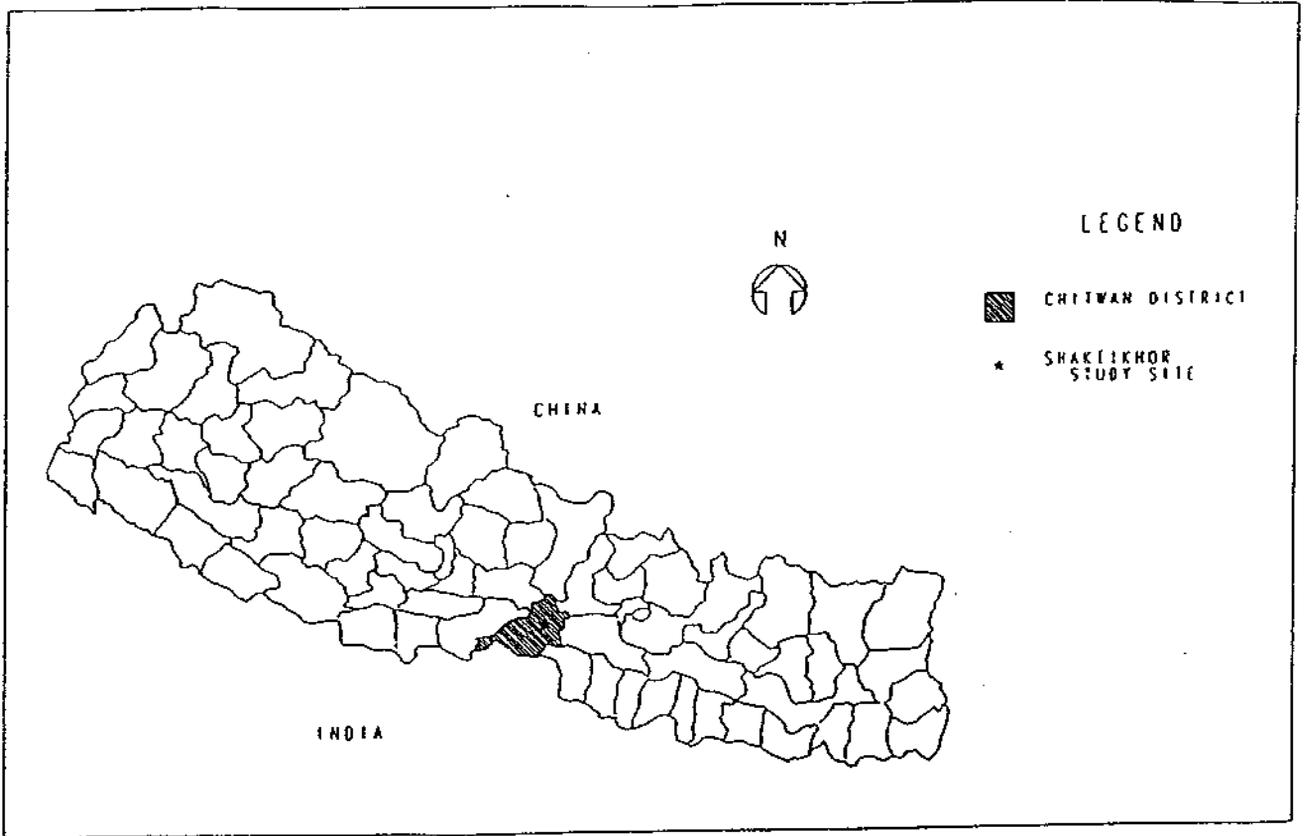
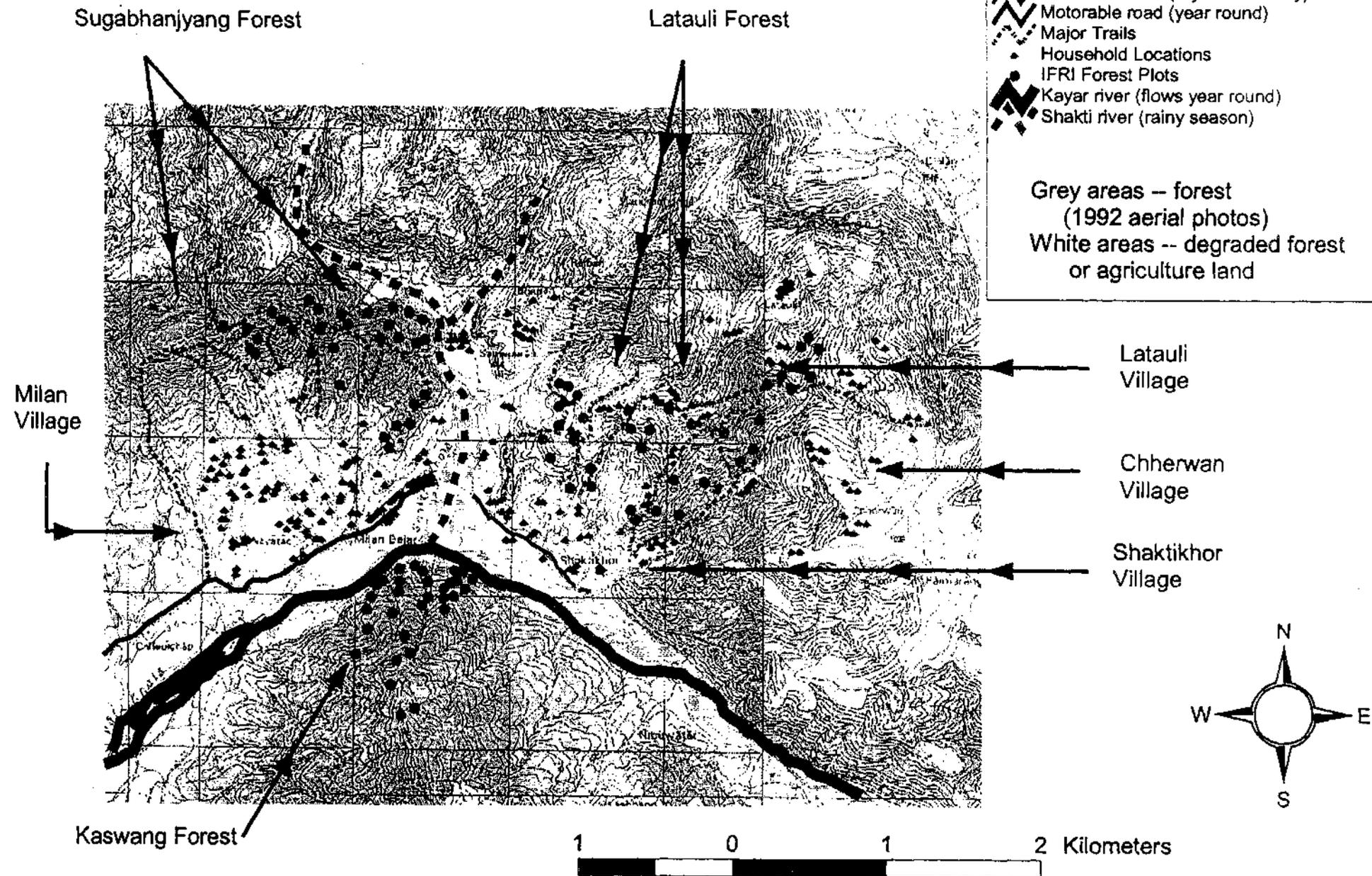


Figure 2: The Study Area



(Topomap source: Survey Department, His Majesty's Government, Nepal)

Figure 3a: Expected Patterns in a “No Human Influence” Scenerio

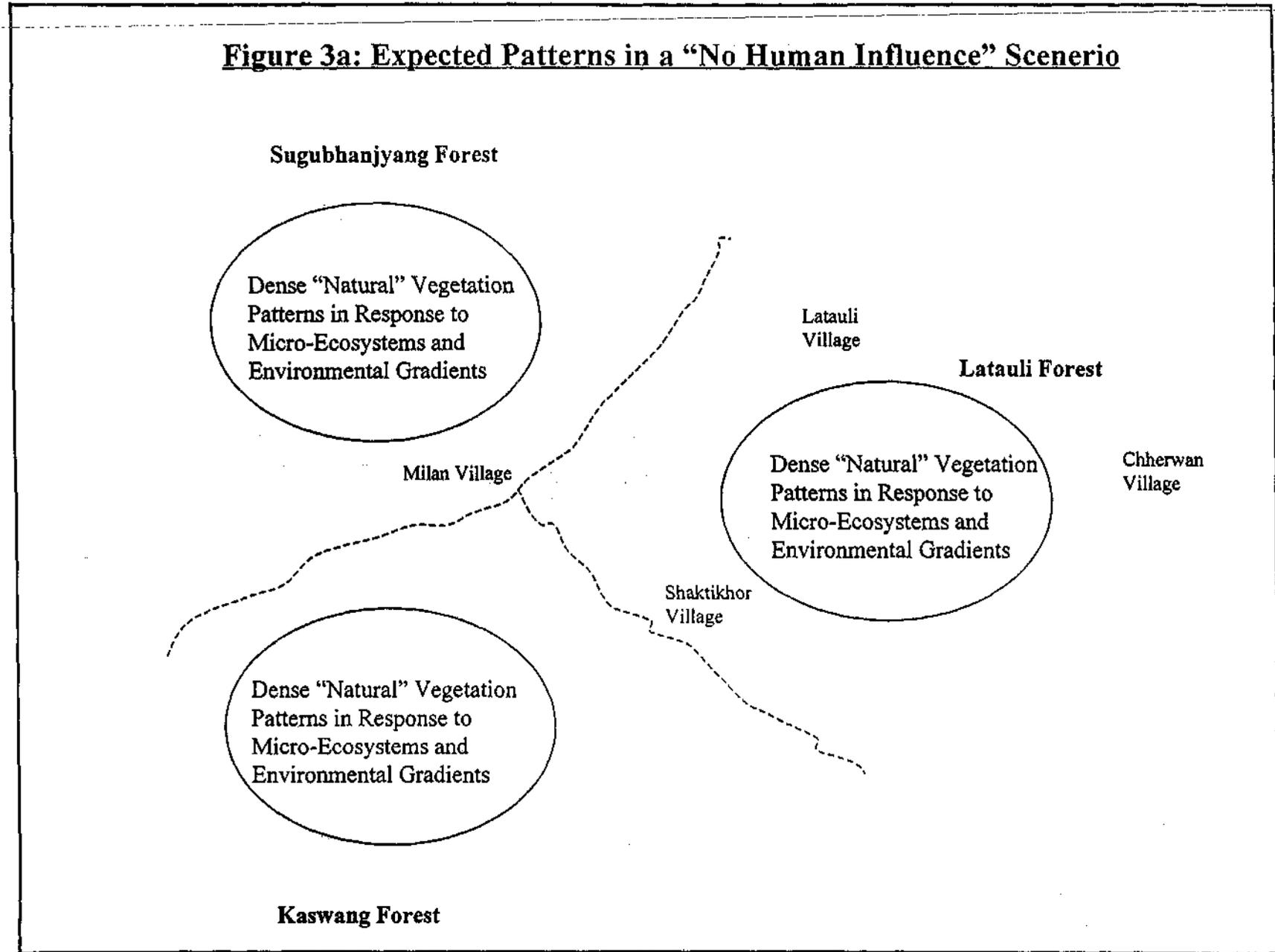


Figure 3b: Expected Patterns as a Result of Open Access and Optimal Foraging

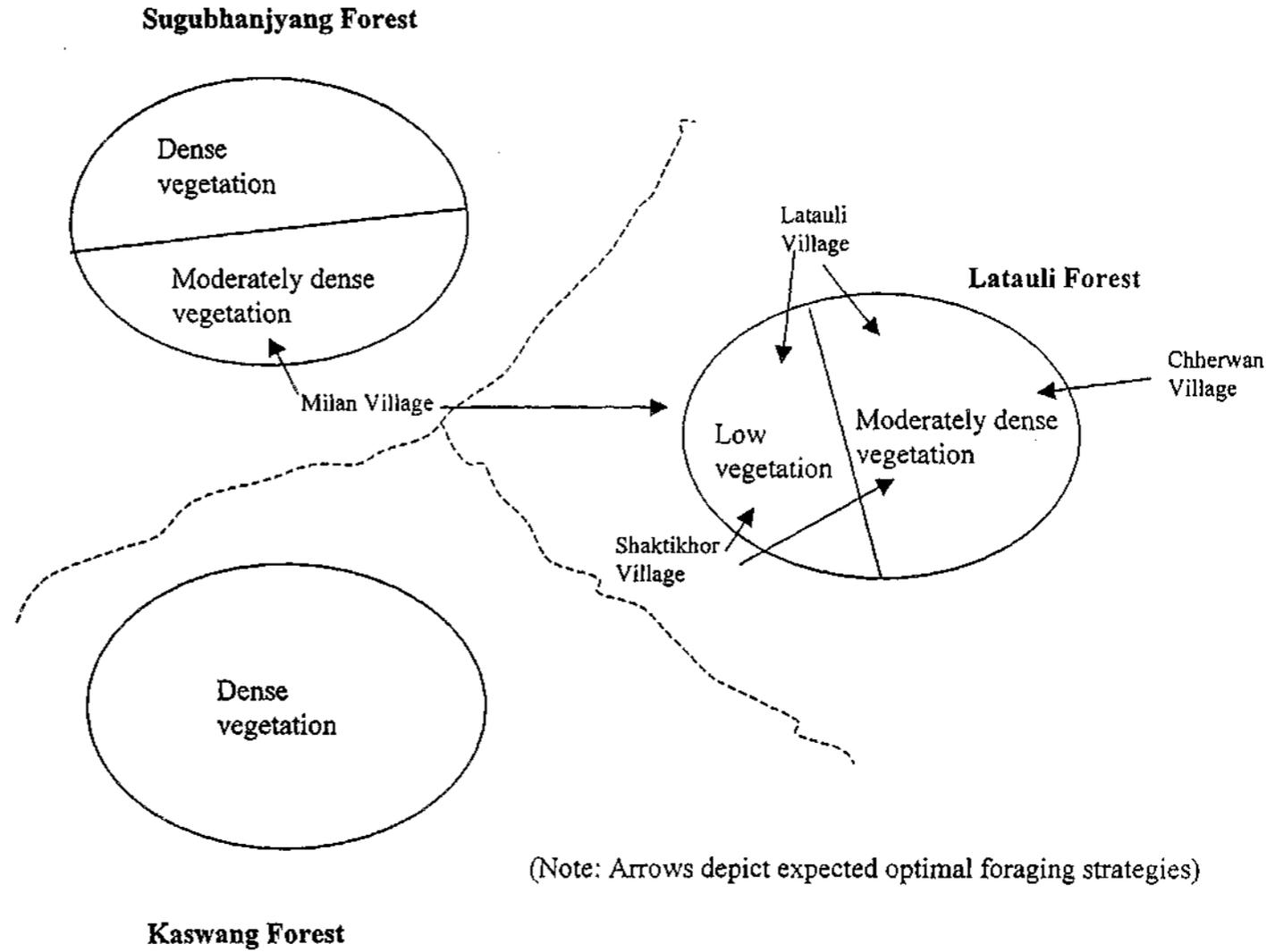
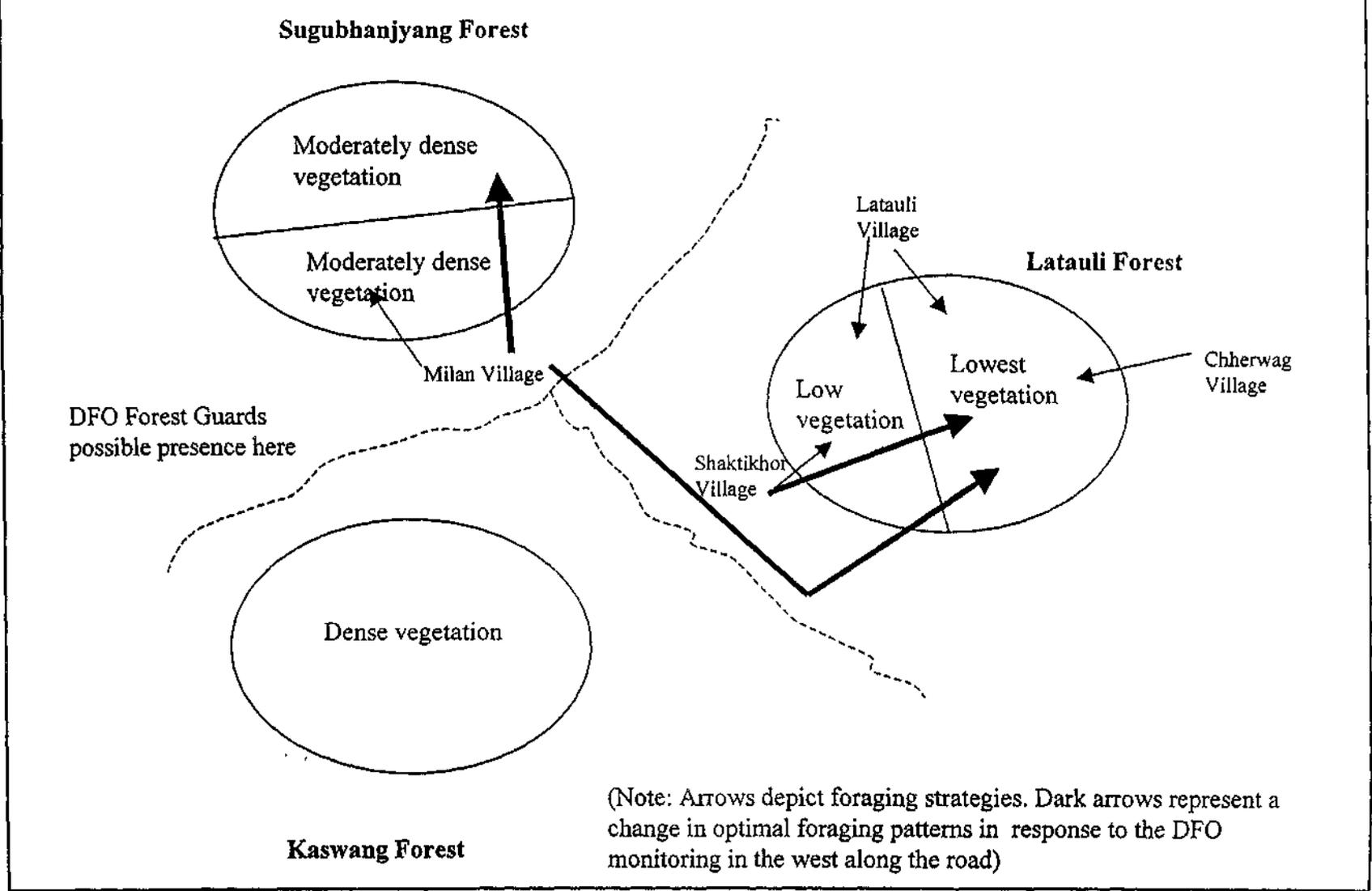


Figure 3c: Patterns as a Result of Optimal Foraging Combined with Institutional Influences



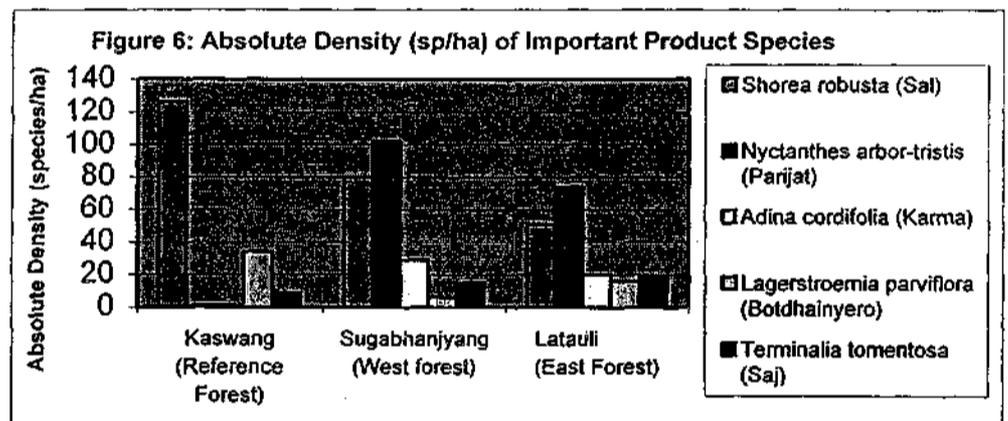
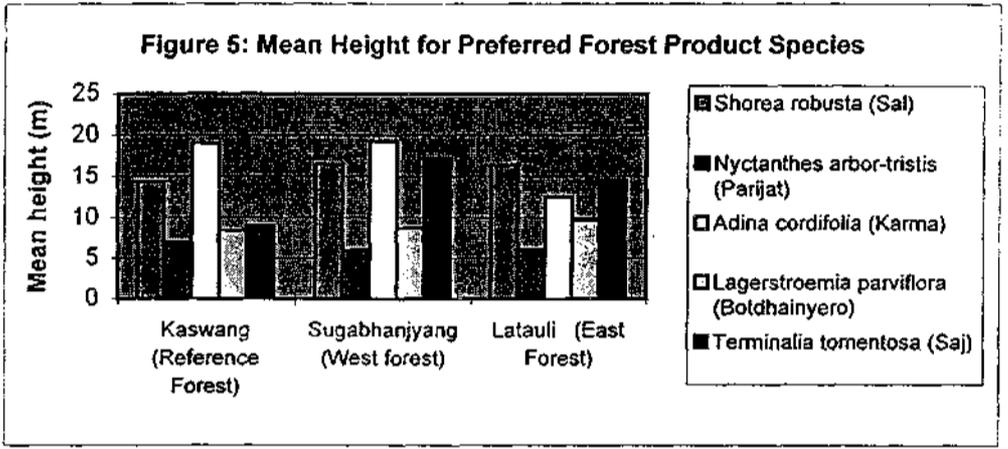
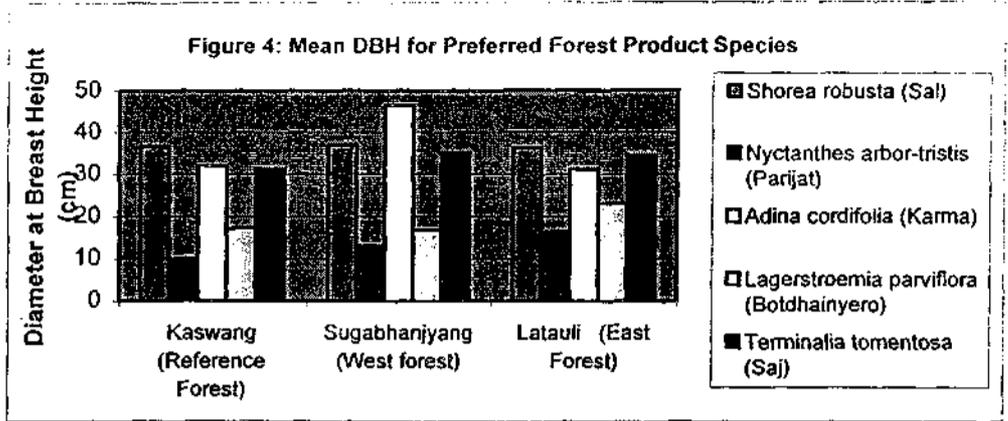


Figure 7: Absolute Frequency of Important Tree Species

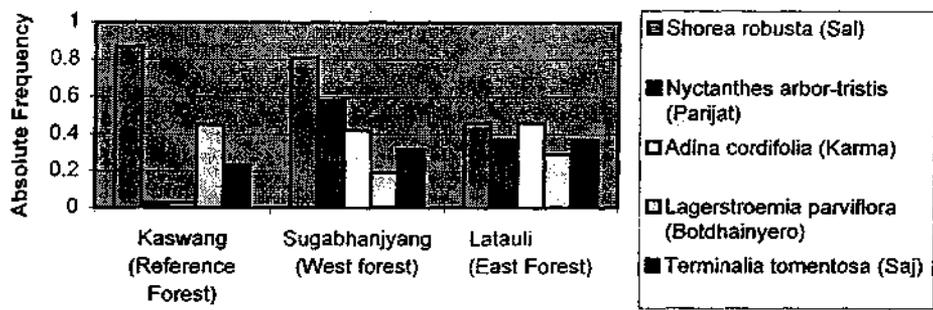


Figure 8: Dominance of Important Tree Species

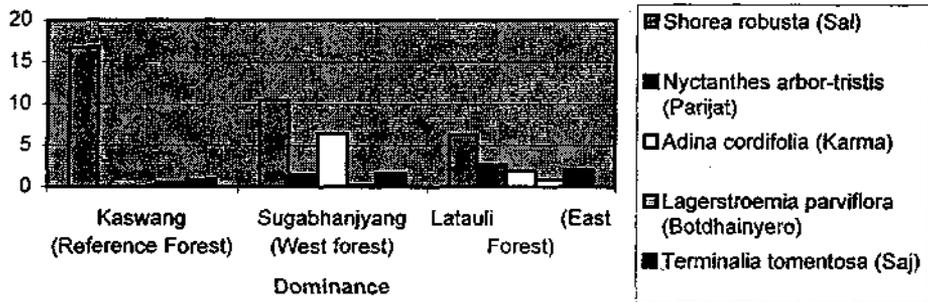


Figure 9: Importance Values for Preferred Tree Species in the Forests of the Shakitkhor Study Area

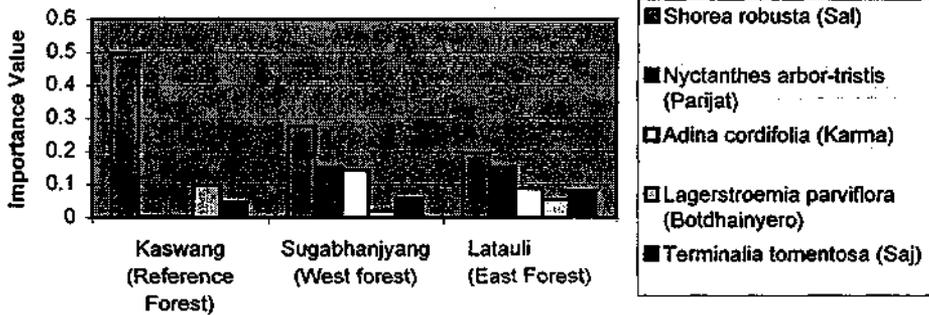


Figure 11: An Example of Household Proximity Analysis of Three Selected Forest Plots (1 kilometer buffer)

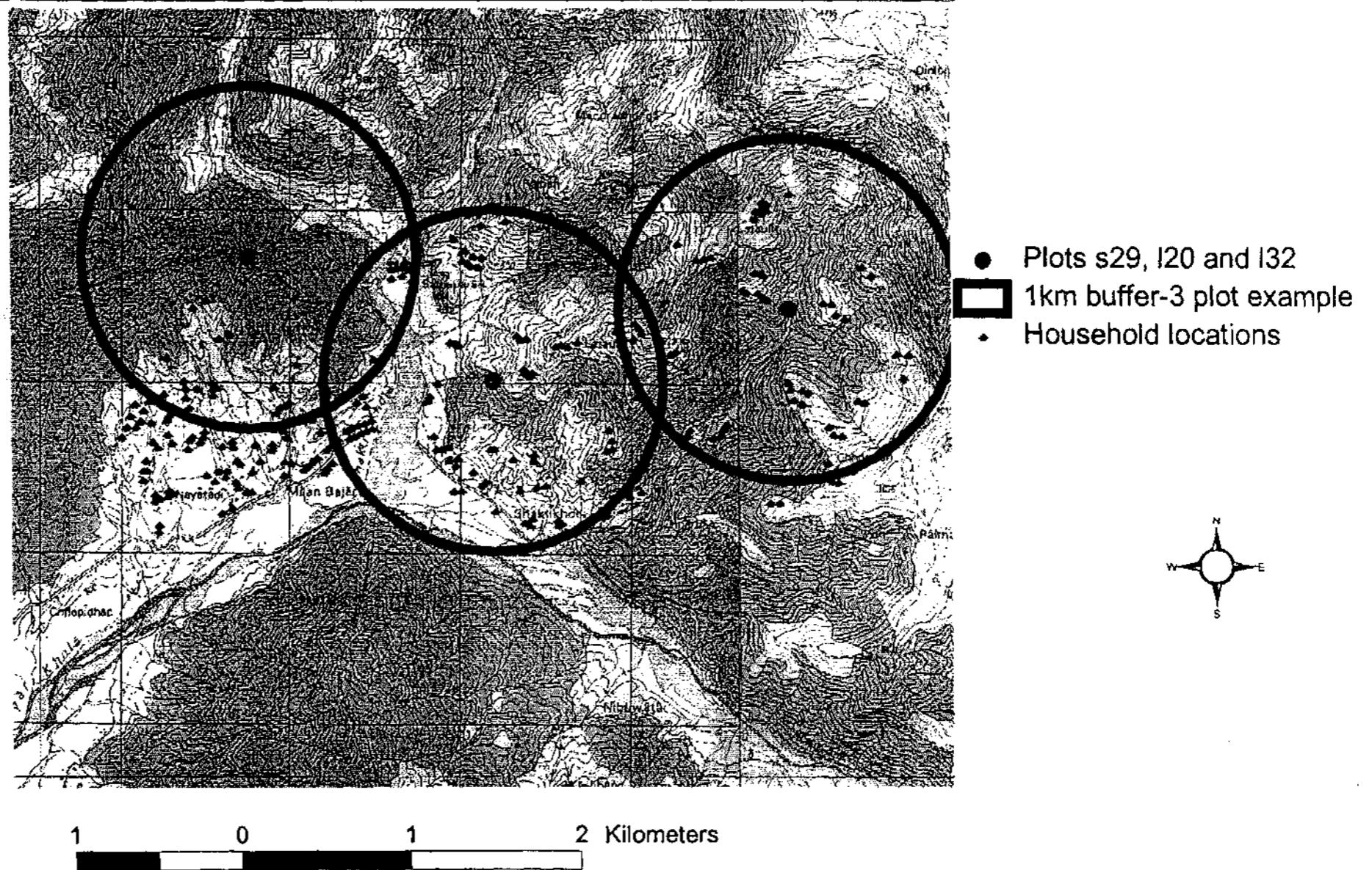


Table 1: Characteristics of the Communities in the Region
(Based on villager estimates, IFRI, 1994)

<u>Community Name</u> (From map")	<u>Associated village names</u> from IFRI study	<u>Estimated # of</u> <u>households</u>	<u>Ethnic groups</u>	<u>Forests</u> <u>Harvested</u>
Milan (West)	Sulitar, Kuwapani, Sinjali gaun, Bhandari gaun, Sewnjaja towe, Milan Chok	110	Chepang, Chettri, Newar, Brahmin, Tamang, Gurung, Magar	Sugabhanjyang, Latauli, Kaswang (rarely)
Shaktikhor (East)	Dogara	58	Chepang, Chettri, Gurung	Latauli
Latauli (East)	Latauli, Deurali	35	Chepang, Chettri, Gurung	Latauli
Chherwan (East)	Chherwan	40	Unknown	Latauli

Table 2: Chi-square Test of the Index of Dispersion of *Shorea robusta* Species in the Kaswang Forest

Average Number of Individuals per Plot	5.968
Number of Plots	31
Variance	12.644
Index of Dispersion (variance/mean ratio)	2.119
X ² statistic [X ² = ID(N-1)]	63.562 †

† Significant at the 99% level of confidence.

**Table 3: Negative Binomial Coefficients for Three Foraging Models
(Dependent Variable Number of *Shorea robusta* Trees in Forest Plots) ***

	Independent Variables	Coefficients	IRR
Abiotic Factors	Slope steepness	-.0238 (.0149)	.9764
	Slope aspect	.0290 (.1277)	1.029
	Elevation	.0040 ‡ (.0016)	1.004
	O horizon (humus layer depth)	-.2120 (.1368)	.8089
	A and B horizon depth	-.0108 (.0368)	.9893
	A and B horizon color	.0729 (.0885)	1.077
	A horizon texture	-.1993 (.2174)	.8193
Biotic Factors	Competing tree biomass	-.0045 † (.0017)	.9955
Human foraging (plot accessibility measures)	Number of households within 1km	.0038 (.0125)	1.004
	Average Distance of households w/in 1km to plot	.0006 (.0020)	1.001
	X coordinate	-.0006 ‡ (.0003)	.9994
	Y coordinate	.00003 (.0009)	1.000
	Intercept	-.1099 (3.059)	----

Negative Binomial log-likelihood: Model 1 -109.773; Model 2 -107.326; Model 3 -107.094 n = 66

*Numbers in parentheses are standard errors.

† Significant at the 99% level of confidence. ‡ Significant at the 95% level of confidence.

§ Significant at the 90% level of confidence.