Mapping resource use over a Russian landscape: an integrated look at harvesting of a non-timber forest product in central Kamchatka

Stephanie K Hitztaler and Kathleen M Bergen

School of Natural Resources and Environment, The University of Michigan, 440 Church Street, Ann Arbor, MI 48109, USA

E-mail: shitztal@umich.edu and kbergen@umich.edu

Received 24 June 2013
Accepted for publication 1 October 2013
Published 30 October 2013
Online at stacks.iop.org/ERL/8/045020

Abstract
Small-scale resource use became an important adaptive mechanism in remote logging communities in Russia at the onset of the post-Soviet period in 1991. We focused on harvesting of a non-timber forest product, lingonberry (Vaccinium vitis-idaea), in the forests of the Kamchatka Peninsula (Russian Far East). We employed an integrated geographical approach to make quantifiable connections between harvesting and the landscape, and to interpret these relationships in their broader contexts. Landsat TM images were used for a new classification; the resulting land-cover map was the basis for linking non-spatial data on harvesters’ gathering behaviors to spatial data within delineated lingonberry gathering sites. Several significant relationships emerged: (1) mature forests negatively affected harvesters’ initial choice to gather in a site, while young forests had a positive effect; (2) land-cover type was critical in determining how and why gathering occurred: post-disturbance young and maturing forests were significantly associated with higher gathering intensity and with the choice to market harvests; and (3) distance from gathering sites to villages and main roads also mattered: longer distances were significantly correlated to more time spent gathering and to increased marketing of harvests. We further considered our findings in light of the larger ecological and social dynamics at play in central Kamchatka. This unique study is an important starting point for conservation- and sustainable development-based work, and for additional research into the drivers of human–landscape interactions in the Russian Far East.

Keywords: Russian Far East, Landsat, remote sensing, land-cover/land-use, small-scale resource use, lingonberry, boreal forest, socio-economic transformation

1. Introduction
Research into human dimensions of environmental change seeks to understand the coupled relationships of natural resource use with ecological and socio-economic changes at the local, regional, and global scales (Lambin and Geist 2006, Liu et al 2007). In the Russian Federation (Russia), the changes associated with the dissolution of the Soviet Union in 1991 have greatly reshaped resource use (Backman 1999, Lerman and Shagaida 2007). The demise of the state-command economy particularly affected Russia’s large forestry and agricultural sectors. In 1991 the forest harvest dropped to approximately one-quarter of its late 1980 levels (Bergen et al 2008) and remains behind this mark today. Large-scale reduction of collective agriculture also occurred...
specifically at harvesting of the NTFP species lingonberry following the dissolution of the Soviet Union. We looked its logging and farming communities occurred abruptly to household-based, small-scale resource consumption in shift from state-driven, large-scale resource exploitation in Kamchatka in the Russian Far East (figure 1). Here the spatial methodology in our study situated in central resource use with remotely sensed data and an explicitly socio-cultural and economic importance (Hitztaler 2010, disturbed forest landscapes in the study area and its high et al 2005, Rindfuss et al 2003b). These studies employed imagery from moderate or coarse spatial resolution sensors to quantify land-cover changes, and confirmed decreases in industrial-scale logging and widespread abandonment of large collective agricultural lands. Not as directly quantifiable through remote sensing alone, however, are the patterns of small-scale adaptive resource use on these landscapes of major socio-economic and land-cover change.

An emerging set of detailed ethnographic and sociological studies have suggested the importance of small-scale resource use in post-Soviet communities in Russia’s boreal zone. These studies show that household garden and livestock production became a primary means of sustenance for many people (Metzo 2001, O’Brien et al 2005, Pallot and Moran 2000, Pallot and Nefedova 2007, Seeth et al 1998, Southworth 2006). People also increasingly turned to their surrounding landscapes from which they acquired a variety of resources, including non-timber forest products (NTFPs; e.g. wild berry species, a variety of mushrooms, and medicinal plants) (Crane 2003, 2008, Pickup and White 2003, Yamin-Pasternak 2008). Households also marketed these resources to generate critical income (Lerman et al 2008, Pallot and Nefedova 2003).

Because small-scale resource use often occurs over landscapes that have been modified by anthropogenic activities, the development of more explicitly spatial approaches to analysis has been a methodological objective of recent studies applied in other areas of the globe. Innovative methods have been employed in household-level case studies to link combinations of biophysical and socio-economic data in geographic and temporal representations (Evans and Moran 2002, Lambin 2003, Liu et al 1999, Rindfuss et al 2003a, Walsh et al 2003). In these endeavors, GIS and spatial analysis have been powerful tools in connecting land cover (often derived from remote sensing) to land use through the linking of resource-use data to land parcels and the land-cover types within these parcels (Evans and Moran 2002, Evans et al 2005, Rindfuss et al 2003b).

We combined detailed ethnographic data on small-scale resource use with remotely sensed data and an explicitly spatial methodology in our study situated in central Kamchatka in the Russian Far East (figure 1). Here the shift from state-driven, large-scale resource exploitation to household-based, small-scale resource consumption in its logging and farming communities occurred abruptly following the dissolution of the Soviet Union. We looked specifically at harvesting of the NTFP species lingonberry (Vaccinium vitis-idaea) given its wide distribution throughout disturbed forest landscapes in the study area and its high socio-cultural and economic importance (Hitztaler 2010, Kabanov 1963). Our guiding research questions were: (1) which landscape factors were associated with harvesters’ choice of lingonberry gathering sites? and (2) which landscape factors affected four gathering behaviors: gathering intensity, time allocated to gathering, number of household members gathering, and the choice to market harvests?

Our initial expectations were formulated within two theoretical contexts. Land-cover/land-use change (LCLUC) science considers how humans have altered landscape patterns, as well as the consequences of this change for subsequent human activities (Rindfuss et al 2004, Turner et al 2004). Optimal foraging theory (OFT) explains how humans or animals optimize their gathering (or foraging) choices under conditions of food and time scarcity (Aswani et al 2001) and the Kamchatka River. Figure 1. Shown is the location of the Kamchatka Peninsula study area in Northern Eurasia (inset) and the study site within central Kamchatka; also shown are ecoregions adapted from WWF (Olson et al 2001) and the Kamchatka River.

Land-use/Land-cover (LCLUC) change (LCLUC) science considers how humans have altered landscape patterns, as well as the consequences of this change for subsequent human activities (Rindfuss et al 2004, Turner et al 2004). Optimal foraging theory (OFT) explains how humans or animals optimize their gathering (or foraging) choices under conditions of food and time scarcity (Aswani et al 2001) and the Kamchatka River. Figure 1. Shown is the location of the Kamchatka Peninsula study area in Northern Eurasia (inset) and the study site within central Kamchatka; also shown are ecoregions adapted from WWF (Olson et al 2001) and the Kamchatka River.
positive relationships between increasing distance (from a gathering site to the nearest village and main road) and greater intensity, time allocation, and marketing; at the same time, an increase in distance should be associated with a decrease in the number of gatherers. Finally, we expected positive relationships between greater accessibility via the extensive forest road network and increases in all four gathering behavior metrics.

The approach that we employed allowed us to test these predictions and make quantifiable connections between resource use and the landscape-level patterns of the study area through the integration of spatial, ecological, and ethnographic data (see Nyerges and Green 2000). Our investigation was conducted through four objectives:

1. Map land-cover type through Landsat image classification coupled with ancillary spatial data;
2. Map lingonberry gathering sites using our existing forest ecological plot data and ethnographic data;
3. Link ethnographic data on harvesters’ gathering decisions and behaviors to specific gathering sites in the landscape;
4. Develop several types of statistical models to identify coupled relationships between complex landscapes and harvesting of lingonberry.

2. Study area

2.1. Geography and ecology

The study area (figures 1 and 2) is situated within an 8071 km$^2$ area within the Central Depression of Kamchatka, formed during the glacial and interglacial periods of the late Pleistocene (Braitseva et al. 2005). The Kamchatka River bisects the study area and proluvial fans formed from the transport of volcanic material are well distributed along the broad valley. Elevation ranges from approximately 20–500 m asl in the river floodplain to 1566 m asl for a study area peak (figure 2, lower right) lying to the southwest of the Tolbachik volcano. Flanked by mountain ranges to the west and east, climate is continental in contrast to the maritime regions of the peninsula. Winters are long with high precipitation levels and frozen topsoil up to 90 cm; summers are short and dry with a vegetative period of only up to 80 days (Hitztaler 2003, Newell 2004).

The Central Depression provides the primary productive habitat for coniferous forests in Kamchatka. Referred to in the vernacular as ‘Conifer Island’ (Newell 2004), these forests constitute the easternmost stretch of Russia’s taiga forests. Larch (Larix dahurica) (Krestov 2003) has historically dominated the low-diversity forest cover, while spruce (Picea ajanensis) is found in sub-montane settings. Today, however, early–successional broadleafed species, primarily birch (Betula platyphylla) accompanied by aspen (Populus tremula), are widespread owing to major anthropogenic disturbance (i.e. logging and fire). The few non-anthropogenic fires in this region are usually sparked by volcanic activity.

Our species of interest, lingonberry, is reported to be most prevalent and productive in disturbed forests where logging and fires have created gaps in the forest canopy that enable its growth due to increased light availability (Kabanov 1963, Yudina et al. 1986).

2.2. Human history

Recognizing the great potential in exploiting Kamchatka’s rich natural resources, the Soviet state initiated an ambitious development program for the peninsula, which included the commencement of large-scale logging and timber processing, in the early 1900s. A steady influx of people from mainland Russia followed, attracted to this remote region by high salaries (Heleniak 2001, Mikheeva 2002). In central Kamchatka people settled in isolated villages, including Kozyrevsk, Lazo, and Atlasovo (figure 2), which were the bases of large forest enterprises (lespromkhozy). In addition to employment, these enterprises built and supported nearly all infrastructure critical to village life. People also came to work in the state and collective farms (sovkhozy and kolkhozy) that supported central Kamchatka’s burgeoning population. The villages of Dolinovka, and later Lazo (figure 2), became the sites of these farms.

The escalating ecological challenge in Kamchatka as available timber was increasingly exploited was compounded
by the pervasive socio-economic crisis that unfolded in Russia after the dissolution of the Soviet Union. The ensuing loss of livelihood and opportunity was devastating: villages changed almost overnight as homes, buildings, and construction projects were quickly abandoned (Hitztaler 2003, 2004, 2010). As self-sufficiency became the survival mechanism for those who remained, a distinct shift in resource-use patterns occurred. In addition to household garden plots, the gathering and preservation of NTFPs became a critical livelihood activity. This dependence on NTFPs, both for sustenance and income, resulted in a sizable increase in volume harvested. To illustrate, one household documented in the ethnographic data (Hitztaler 2010) reported gathering 10 l of mushrooms and lingonberry a piec e each year during the Soviet period. In the post-Soviet period these amounts jumped to 70 l of mushrooms and 300 l of lingonberry annually.

3. Methods

3.1. Landsat land-cover classification

We obtained two mostly cloud-free Landsat TM (Thematic Mapper) Level 1T (terrain corrected) satellite images from 23 July 2007 for path 99, rows 21 and 22. Image pre-processing included cloud removal, atmospheric correction using the COST method (Chavez 1996), and subsetting the images to the study area. We performed unsupervised classification using the ISODATA algorithm in ERDAS IMAGINE 9.2 (Leica Geosystems 2009). Ancillary data were important in developing a land-cover classification scheme (table 1) and assigning clusters to land-cover classes. These data included our own large set of geolocated field photos, ecological literature, and Russian 1:100 000 topographic maps (Roskartografia 2001). Reference data had been previously created from the forest plot data (N = 43, Hitztaler 2010) and 364 additional testing pixels were collected from visual interpretation of unclassified Landsat imagery and topographic maps. Based on these, we calculated the overall, producer’s, and user’s accuracies.

We created vector data in ArcMap 9.3.1 (ESRI 2009) based on the topographic maps and the Landsat imagery (figure 2). Land cover that was difficult to distinguish using digital image classification included villages and agricultural fields. These land covers were manually digitized, rasterized, and then merged with the results of the digital classification. Roads (all unpaved) were digitized and classified into primary, intermediate, and forest classes: primary roads connect villages in central Kamchatka to the cities of Petropavlovsk-Kamchatsky (capital) and Elizovo in southeast Kamchatka; intermediate roads are arterial roads within forested areas; and forest roads are least traveled and maintained.

3.2. Mapping lingonberry gathering sites

Using the forest plot and ethnographic data collected in 2004, 2006 and 2008 (Hitztaler 2010), we delineated initial lingonberry gathering sites on the land-cover type map. The GPS coordinates associated with these data were used to represent the center of gathering sites from which radial buffers with a 1-km radius were grown. This radius was chosen to create an area that could encompass patchy lingonberry harvests; it was also a reasonable amount to travel within a site, on foot or by vehicle. We then dissolved the boundaries of each radial buffer to create 32 polygons representing lingonberry gathering areas, and assigned each with a GIS site ID.

We created a household-level gathering behavior dataset based on the ethnographic survey data. We then grouped responses together based on gathering site ID and calculated the following variables for each of the 32 sites: sum of households that gathered; sum of individual gatherers and per cent of the total number of gatherers (in all sites); mean gathering intensity (liters gathered/hour); mean number of hours gathered; and per cent of households that sold their harvests. We added these aggregate data as variables to the GIS attribute table for the 32 gathering sites. These steps enabled the linking of harvesting households to the landscape, or the joining of non-spatial and spatial data.

We added other essential data on each gathering site to the GIS attribute tables, including its total area and the proportion of each land-cover type within the site. We also entered least-cost distances from the gathering sites to the villages and to the primary road. Least-cost distances were based on actual routes that gatherers could take via roads; they were calculated using the cost-distance and cost-path functions in ArcMap. Finally, to estimate general accessibility levels within the sites, we computed and entered the road density in each site.

3.3. Statistical analysis

We first analyzed correlations between mapped land-cover types in gathering sites and (1) distance from villages or primary roads, and (2) density, using bivariate correlation models in SPSS 17.0.3 (2009). (Note that for these and subsequent models only the land-cover types 1–9 were tested, see table 1.) Next, to establish whether the factors of land-cover type, distance, road density, and year (2003 or 2006) affected harvesters’ decisions to gather in a certain site, we ran binary logistic models in SPSS. In these models we combined the 2003 and 2006 data sets to obtain a sample size of N = 64 sites and entered year as the within-subject effect and gathering site ID number as the subject effect. The dependent binary variable was gathering occurrence (yes or no); the covariates (i.e. continuous variables) were the following: proportions of land-cover types within sites, least-cost distance in km from site to nearest village, least-cost distance from site to primary road artery, and road density in sites. Lastly, to investigate the effects of land-cover type, distance, and road density on four gathering metrics of intensity, total hours spent gathering, total number of gatherers, and marketing of harvests we used linear mixed models. Similar to the binary logistic models, we combined the same data sets and ran these models in SPSS where year was treated as a repeated effect. The gathering metrics were
Table 1. Landsat classification land-cover types, definitions, classification accuracies, and land-cover area proportions within the study site and the gathering sites.

| Class         | Landsat land-cover type | Ecological description                                                                 | Producer's/user's accuracy (%) | Proportion (%) of total study site area | Proportion (%) of total gathering sites area |
|---------------|-------------------------|----------------------------------------------------------------------------------------|--------------------------------|----------------------------------------|---------------------------------------------|
| 1             | Spruce                  | Undisturbed or mature spruce (*Picea ajanensis*) forests                                | 96/96                          | 7.3                                    | 1.2                                         |
| 2             | Larch                   | Undisturbed or mature larch (*Larix dahurica*) forests                                  | 73/85                          | 5.7                                    | 7.8                                         |
| 3             | Fragmented Mixed-Larch | Disturbed mixed forests, larch-dominant (*Larix dahurica*)                              | 85/84                          | 18.3                                   | 30.5                                        |
| 4             | Fragmented Mixed-Birch  | Disturbed mixed forests, birch-dominant (*Betula platyphylla*)                         | 71/83                          | 5.7                                    | 10.7                                        |
| 5             | Maturing Broadleaved    | Birch forest, maturing from past regeneration                                          | 81/74                          | 7.8                                    | 13.4                                        |
| 6             | Young Broadleaved       | Young birch forest (with aspen, alder, and willow; *Populus tremula, Alnus hirsuta, Salix spp*) following recent regeneration<sup>a</sup> | 82/94                          | 10.3                                   | 8.7                                         |
| 7             | Shrub                   | Woody-dominated regeneration following disturbance                                      | 89/91                          | 12.8                                   | 18.5                                        |
| 8             | Herbaceous              | Herbaceous-dominated regeneration following disturbance                                 | 92/85                          | 3.5                                    | 1.4                                         |
| 9             | Bare                    | Very recently logged or burned area, sandbars, dry volcanic rivers, mudflats            | 100/83                         | 3.1                                    | 3.1                                         |
| 10            | High elevation Larch    | High elevation larch–Siberian dwarf pine (*Larix dahurica–Pinus pumila*) forests       | 100/100                        | 9.1                                    | 1.0                                         |
| 11            | High elevation Broadleaved | High elevation stone birch–alder (*Betula ermanii–Alnus fruticosa*) forests            | 100/91                         | 7.6                                    | 0.2                                         |
| 12            | High elevation Bare     | Rocky outcrops on mountaintops                                                         | 93/100                         | 0.7                                    | 0.0                                         |
| 13            | Wetlands                | Lowland bogs/floodlands                                                                 | 91/79                          | 6.2                                    | 2.4                                         |
| 14            | Water                   | Rivers, streams, lakes                                                                  | 93/100                         | 1.1                                    | 0.1                                         |
| 15            | Agriculture             | Active and fallow fields                                                                | 83/94                          | 0.7                                    | 0.9                                         |
| 16            | Villages                | Settlements                                                                             | 77/100                         | 0.1                                    | 0.1                                         |
| **Overall totals** |                        | **88**                                                                                 | **100**                        | **100**                                | **100**                                     |

<sup>a</sup> Because of species and spectral similarities the class also contains lesser occurrences of short stature riparian forest.

the dependent variables, while the covariates (i.e. continuous variables) were the proportions of land-cover types, distance, and road density. The subject variable was the gathering site ID number.

4. Results

4.1. Land cover and anthropogenic features of the study area

The overall classification accuracy of the land-cover map was 88%; producer’s/user’s accuracies were between 71%–100% (table 1 and appendix). The map (figure 3) and derived land-cover proportions (table 1) indicate a complex landscape with forest types patterned by elevation, and by disturbance, regeneration, or maturation stage. Villages are small and located near the Kamchatka River or one of its tributaries. Gathering sites are generally located in low to mid-elevation upland terrain and distributed over the north–south range of the study site. Predominant land-cover types in gathering sites are: fragmented mixed-larch, shrub, maturing broadleaved, fragmented mixed-birch, and young broadleaved. A primary
Figure 3. Land-cover type map classified from Landsat TM. Also shown are mapped gathering sites and villages. Village names appear in black; names of more well-known gathering sites appear in gray italic.

Table 2. Bivariate correlation matrices. Distance and accessibility (road density) are the independent variables; land-cover type is the dependent variable.

| Matrix | Variable | Land-cover type | Pearson correlation | Significance |
|--------|----------|-----------------|---------------------|--------------|
| 1      | Distance (km from site to nearest village) | Larch | −0.394 | 0.026* |
|        |          | Herbaceous      | 0.390 | 0.027* |
| 2      | Distance (km from site to nearest primary road) | Fragmented mixed-birch | −0.346 | 0.052b |
| 3      | Accessibility (density of primary roads) | Fragmented mixed-birch | 0.314 | 0.080b |
| 4      | Accessibility (density of forest roads) | Maturing broadleaved | 0.315 | 0.079b |
|        |          | Fragmented mixed-birch | 0.298 | 0.097b |
|        |          | Maturing broadleaved | 0.446 | 0.010a |
|        |          | Bare            | −0.325 | 0.069b |

* Significance is 2-tailed, with significant at the 0.05 level.

b Significance is 2-tailed, with significant at the 0.1 level.

road bisects the study site from north to south and there are concentrations of numerous forest roads (figure 2).

4.2. Statistical results

The results of the bivariate correlation models showed significant associations of distance and road density with land-cover type (table 2). As distance from gathering sites to the nearest village increased (1) larch forests in gathering sites significantly decreased; and (2) herbaceous-dominated land cover in sites significantly increased (table 2, matrix 1). Further, with each 1-km increase from the primary road to gathering sites, fragmented mixed-birch forests in sites decreased (table 2, matrix 2). These models also indicated a significant positive correlation between increasing densities of primary and forest roads in gathering sites and increases in maturing broadleaved and fragmented mixed-birch forests in these sites (table 2, matrices 3 and 4). The strongest correlation was between forest road density and maturing broadleaved forests. Greater forest road density was also significantly related to decreasing proportions of bare land.

Binary logistic models corroborated a significant effect of year, land-cover type, and distance on harvesters’ decisions to gather. Of the significant results, the parameter estimate of β (beta coefficient) showed that gathering was more likely to occur in 2003 than it was in 2006 (table 3, model 1). Second, the land-cover types of spruce forest, young broadleaved, and bare land in sites significantly influenced the probability of gathering (table 3, models 2–4). As spruce forests increased within a gathering site, the probability of gathering in this site decreased. In contrast, higher proportions of young broadleaved and bare land in sites corresponded to a higher probability of gathering in these sites. Third, increasing distance from a gathering site to the nearest village and primary road significantly corresponded to decreased likelihood of gathering in that site (table 3, models 5 and 6).

Linear mixed models confirmed a significant negative relationship between larch forests and the metrics of intensity...
Table 3. Binary logistic models (type III). The dependent variable is the response of gathering in a particular site: 1 = yes, or 0 = no. The covariates (or continuous independent variables) are: land-cover type (types 1–9, table 1) and distance (km) from gathering site to nearest village or primary road. Each covariate was modeled separately, and year was controlled for in each model.

| Model | Covariate                        | Beta | Wald chi-square | df | Significance |
|-------|----------------------------------|------|-----------------|----|-------------|
| 1     | Year (2003, 2006)                | 0.631| 2.943           | 1  | 0.086b      |
| 2     | Proportion of spruce             | −9.245| 5.425           | 1  | 0.020a      |
| 3     | Proportion of young broadleaved  | 14.720| 4.748           | 1  | 0.029a      |
| 4     | Proportion of bare               | 6.707| 3.619           | 1  | 0.057b      |
| 5     | Distance (km) from site to nearest village | −0.039| 3.309           | 1  | 0.069b      |
| 6     | Distance (km) from site to nearest primary road | −0.053| 2.929           | 1  | 0.087b      |

a Significant at the 0.05 level.
b Significant at the 0.1 level.

Table 4. Linear mixed models—land-cover type. The dependent variables are the gathering metrics of intensity, number of hours spent gathering, number of gatherers, and marketing. The predictors are: land cover (types 1–9, table 1). Each covariate was modeled separately, and year was controlled for in each model.

| Model | Covariate (proportion of land-cover type in gathering site) | Dependent variable | Estimate | Standard error | T   | df | Significance |
|-------|------------------------------------------------------------|--------------------|----------|----------------|-----|-----|-------------|
| 1     | Larch                                                      | Intensity          | −7.183   | 3.997          | −1.797| 20.934| 0.087b      |
| 2     | Maturing Broadleaved                                       | Intensity          | 13.472   | 5.700          | 2.363| 15.499| 0.032a      |
| 3     | Young Broadleaved                                          | Intensity          | 11.544   | 5.632          | 2.050| 14.132| 0.059b      |
| 4     | Larch                                                      | Hours spent gathering | −50.198| 26.236        | −1.913| 16.712| 0.032a      |
| 5     | Bare                                                       | Number of gatherers | 0.314    | 0.136          | 2.308| 19.222| 0.032a      |
| 6     | Maturing Broadleaved                                       | Marketing          | 1.481    | 0.675          | 2.195| 13.284| 0.046a      |

a Significant at the 0.05 level.
b Significant at the 0.1 level.

Table 5. Linear mixed models—distance. The dependent variables are the gathering metrics intensity, hours spent gathering, number of gatherers, and marketing. The predictors are distance (km): (1) from site to nearest village; and (2) site to nearest primary road. Each covariate was modeled separately, and year was controlled for in each model.

| Model | Covariate distance (km) | Dependent variable | Estimate | Standard error | T   | df | Significance |
|-------|-------------------------|--------------------|----------|----------------|-----|-----|-------------|
| 1     | Site to nearest village | Intensity          | 0.046    | 0.034          | 1.347| 17.286| 0.195      |
| 2     | Site to nearest village | Hours spent gathering | 0.536  | 0.210          | 2.551| 14.441| 0.023a     |
| 3     | Site to nearest village | Number of gatherers | 0.005    | 0.004          | 1.281| 15.918| 0.218      |
| 4     | Site to nearest village | Marketing          | −0.0001  | 0.001         | −0.848| 19.739| 0.407      |
| 5     | Site to nearest primary road | Intensity       | 0.089    | 0.100         | 0.892| 25.228| 0.381      |
| 6     | Site to nearest primary road | Hours spent gathering | 1.532  | 0.599         | 2.558| 23.961| 0.017a     |
| 7     | Site to nearest primary road | Number of gatherers | −0.0001| 0.002        | −0.107| 21.051| 0.916      |
| 8     | Site to nearest primary road | Marketing         | 0.020    | 0.011         | 1.813| 24.975| 0.082b     |

a Significant at the 0.05 level.
b Significant at the 0.1 level.

and hours spent gathering (table 4, models 1 and 4). In contrast, rising intensity was significantly associated with higher proportions of maturing broadleaved forests and young broadleaved (table 4, models 2 and 3). Further, increases in bare land and maturing broadleaved forests were significantly related to more gatherers present at a site, and to a greater occurrence of marketing among gatherers, respectively (table 4, models 5 and 6). Models showed no significant effect of year (not shown in table 4) on gathering intensity and marketing. Year did, however, have a significant effect on total hours spent gathering in a season ($p = 0.023$). In 2003 harvesters spent less time gathering than in 2006.

A second set of linear mixed models established that longer distances from a gathering site to the nearest village and primary road were significantly associated with more hours spent gathering (table 5, models 2 and 6). There was also a significant relationship between increasing distance from a gathering site to the primary road and an increase in the percentage of gatherers who sold their harvests (table 5, model 8).

5. Discussion

In this section we elaborate upon the several significant relationships that emerged in our analyses to gain a deeper perspective on NTFP harvesting dynamics in central Kamchatka. We do so by contextualizing them vis-à-vis theory as well as the broader spatial, ecological, social, and temporal backgrounds in which they are embedded.
5.1. Land-cover/land-use characteristics of gathering locations

We first sought to understand the location of gathering sites in relation to anthropogenic features (e.g. villages and roads) and LCLU. Higher proportions of disturbed land-cover types, i.e. fragmented mixed-larch, fragmented mixed-birch, maturing broadleaved, and shrub, all of which provide ample light penetration conducive to lingonberry fruiting, clearly distinguished gathering sites (table 1). Given the region’s logging history, we predicted a positive correlation between longer distances (from gathering sites to the nearest village and primary road) and these disturbed land-cover types. While our statistical results did not show significant associations of distance with specific young and maturing forest types, they nonetheless outlined an expected general pattern: as distance from sites to villages grew, mature forests decreased, while landscapes in the earliest regeneration stages increased. Recent logging in the few remaining primary forests on the northwestern rim of the Central Depression has continued this pattern (Hitztaler 2010).

We also considered the accessibility of favorable gathering sites by looking at road density within them. Given that the forest road network steadily expanded in step with heightened logging activity in the late Soviet period we expected high road density to be significantly associated with post-disturbance young or maturing forests. Our results firmly corroborated the link between such forests and higher road densities. In sum, these analyses presented a clearer picture of spatial and ecological patterns: favorable sites characterized by higher proportions of post-disturbance young or maturing forests occurred further from villages, yet were nonetheless accessible due to the high density of roads within them.

5.2. Harvesters’ decisions of where to gather on the landscape

The results on factors affecting harvesters’ initial decision to gather in a site further explained the patterns we identified. While distance (from sites to both nearest village and primary road) was a limiting factor, land-cover type proved more influential on these decisions, reinforcing other studies that identified vegetation type as a key factor in natural resource use (Cocks et al 2008). Although our statistical tests emphasized the effect of individual land-cover types on the choice to gather, the resulting relationships should be interpreted within a landscape context. Consider, for instance, the strong positive influence of young broadleaved forests on harvesters’ choice to gather in a site. Lingonberry typically does not fruit in such dense regrowth. Abundant harvests, however, may be found within other land-cover types (e.g. fragmented mixed forest and shrub) among which young broadleaved forests are interspersed in a complex mosaic, as is often the case in a patchy post-fire or logging landscape. (The gathering site of Lokhmataya, figure 3, is an excellent example of such a landscape.)

These spatial relationships that we corroborated quantitatively were intuitively understood by most gatherers in central Kamchatka. Referred to as local ecological knowledge (LEK) in the literature (Huntington 2000), gatherers have cultivated a working knowledge of ecological processes over a disturbed and expansive landscape through years spent in the forest, often as both loggers and gatherers. Our ethnographic work drew out this LEK, revealing gatherers’ often clear grasp of lingonberry ecology and the connection between abundant lingonberry harvests and more recently disturbed forest landscapes (Hitztaler 2010). Gatherers were also keenly aware of the dynamic spatial redistribution of NTFPs, noting the disappearance of nearby harvests as logged forests surrounding villages enter into later maturation stages.

5.3. How gathering occurs on the landscape

We demonstrated that land-cover type, distance, and road density influenced where gathering activity takes place. Next we specified how these factors shaped gathering behaviors. Harvesters gathered more intensely on landscapes where young or maturing forests were present, and were more likely to sell their harvests collected from these forests. They also spent more time gathering in sites further from villages and primary roads. In this case, in accordance with OFT, gatherers appeared to optimize time allocation as well as patch (i.e. site) selection upon the basis of mean harvest rate for that site (see Smith 1983). Applying this patch-choice optimality concept, we would also expect to find a significant positive association between increasing distances and gathering intensity. Our results, however, did not support this correlation, pushing us to think further about how shifting socio-economic circumstances have conditioned post-Soviet gathering behaviors. For instance, the urgency of NTFP harvesting may have subsided as economic hardship has more recently lessened in central Kamchatka. Moreover, better times have meant a rise in car ownership, making it easier for more harvesters, including less focused ones, to travel further distances to sites.

6. Conclusions

Our study linked the coupled relationships of NTFP harvesting activity to the striking ecological and social changes that have defined central Kamchatkan landscapes in the late Soviet and more recent post-Soviet periods. Linking non-spatial data on lingonberry gathering practices to the spatial data on gathering sites enabled us to do quantitative analyses of (1) the relationship between specific land-cover types and anthropogenic landscape features; and (2) the effects of land-cover type, distance, and accessibility on gathering decisions and behaviors. Occurrence of young or maturing forests proved to be the most important factor influencing gathering choices and behaviors. Distance was also a factor; although its effect was not as clear, especially as the post-Soviet phenomenon of individual car ownership has increasingly facilitated travel to more remote gathering sites.

In sum our examination revealed an intricate picture of resource use in central Kamchatka that is a product of both past and present land- and resource-use practices and is changing in response to dynamic ecological and social
changes. We have to date conducted the most comprehensive and integrative analyses of small-scale, non-timber forest product gathering in a remote forest area in Russia. These analyses have strong potential implications for both future research and policy-making on natural resource use and conservation in the region. Our results also elicit further inquiries into the major processes that have driven the observed interactions between inhabitants and their landscape during a period of heightened dependence on local natural resources.

Acknowledgments

We would like to acknowledge support by the NASA Land-Cover/Land-Use Change (LCLUC) program under grants NNX08AW51G and NNX12AD34G and the National Science Foundation (NSF) Doctoral Dissertation Research Improvement Grant, Office of Polar Programs, Arctic Social Sciences Program under grant ARC0526040. We appreciate the insights and expertise of Dr Bobbi Low of the University of Michigan School of Natural Resources and Environment, and of Kathy Welch of the University of Michigan Center for Statistical Consulting and Research. We thank the following staff of the University of Michigan Environmental Spatial Analysis Laboratory for technical assistance: Shannon Brines, Nadia Roumie, Peter Gamberg, Jillian Estrada and Tim Johnson. We are also grateful for the expertise and logistical assistance generously offered by the Forest Service (leskhoz) directors and staff in the villages of Kozyrevsk and Atlasovo. Finally, we thank the anonymous reviewers of the manuscript for their useful critiques and suggestions.

Appendix

See table A.1.

References

Aswani S and Lauer M 2006 Incorporating Fishermen’s local knowledge and behavior into geographical information systems (GIS) for designing marine protected areas in Oceania *Hum. Organ.* **65** 81–102

Backman C A 1999 The Siberian forest sector: challenges and prospects *Post-Sov. Geogr. Econ.* **40** 453–69

Baumann M, Ozdogan M, Kuemmerle T, Wendland K J, Esipova E and Radeloff V C 2012 Using the Landsat record to detect forest-cover changes during and after the collapse of the Soviet Union in the temperate zone of Europe *Remote Sens. Environ.* **124** 174–84

Bergen K M, Hitztaler S K, Kharuk V, Krankina O N, Loboda T V, Zhao T, Shugart H H and Sun G 2013 Human dimensions of environmental change in Siberia *Regional Environmental Changes in Siberia and their Global Consequences* ed P Groisman and G Gutman (New York: Springer) pp 251–302

Bergen K M, Zhao T, Kharuk V, Blam Y, Brown D G, Peterson L K and Miller N 2008 Changing regimes: forested land cover dynamics in central Siberia 1974–2001 *Photogramm. Eng. Remote Sens.* **74** 787–98

Braitseva O A, Melekestsev I V and Sulerzhitskii L D 2005 New data on the pleistocene deposits in the central Kamchatka depression *Stratigr. Geol. Correl.* **99** 99–107

Chavez P S 1996 Image-based atmospheric corrections revisited and improved *Photogramm. Eng. Remote Sens.* **62** 1025–36

Cocks M L, Bangay L, Shackleton C M and Wiersum K F 2008 ‘Rich man poor man’—inter-household and community factors influencing the use of wild plant resources amongst rural households in South Africa *Int. J. Sustain. Dev. World Ecol.* **15** 198–210

Table A.1. Contingency matrix produced from the accuracy assessment of the Landsat land-cover type classification. Producer’s quantifies how well the set of reference pixels of a particular class were classified and user’s quantifies the probability that a pixel classified into a given class actually represents that class on the ground (Lillesand et al 2007).

| Classified map | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total | User’s (%) |
|----------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|-------|-----------|
| 1 Spruce       | 22 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 95.6     |
| 2 Larch        | 0  | 11| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 84.6     |
| 3 Fragmented   | 1  | 4 | 52| 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 62 | 83.9     |
| 4 Fragmented   | 0  | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 83.3     |
| Mixed-Birch    | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0       |
| Maturing Broadleaved | 0  | 0 | 2 | 1 | 17| 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 73.9     |
| Young Broadleaved | 0  | 0 | 1 | 0 | 1 | 32| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 94.1     |
| Shrub          | 0  | 0 | 1 | 0 | 2 | 0 | 39| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 90.7     |
| Herbaceous     | 0  | 0 | 0 | 0 | 0 | 0 | 1 | 22| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 84.6     |
| Bare           | 0  | 0 | 0 | 0 | 0 | 0 | 1 | 19| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 82.6     |
| 10 High Elev Larch | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 23| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 100.0    |
| 11 High Elev Broadleaved | 0  | 0 | 0 | 1 | 0 | 1 | 0 | 30| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 90.9     |
| 12 High Elev Bare | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 100      |
| 13 Wetlands    | 0  | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 1 | 1 | 38 | 78.9     |
| 14 Water       | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 100      |
| 15 Agriculture | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 15| 16 | 93.7     |
| 16 Villages    | 0  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 100.0    |

Total | 23 | 15 | 61 | 14 | 21 | 39 | 44 | 24 | 19 | 23 | 30 | 15 | 33 | 15 | 18 | 13 | 407

Producer’s (%) | 95.6 | 73.3 | 85.2 | 71.4 | 80.9 | 82.0 | 88.6 | 91.7 | 100 | 100 | 100 | 93.3 | 90.9 | 93.3 | 83.3 | 76.9 | Overall (%) 88.5
Crate S A 2003 Viliui Sakha post-Soviet adaptation: a subarctic test of Netting's smallholder-household theory *Hum. Ecol.* **31** 499–528

Crate S A 2008 ‘Eating hay’: the ecology, economy and culture of Viliui Sakha smallholders of northeastern Siberia *Hum. Ecol.* **36** 161–74

de Beurs K M, Wright C K and Henebry G M 2009 Dual scale trend analysis for evaluating climatic and anthropogenic effects on the vegetated land surface in Russia and Kazakhstan *Environ. Res. Lett.* **4** 045012

Eikeland S and Riabova L 2002 Transition in a cold climate: management regimes and rural marginalisation in northwest *Russia Sociol. Ruralis* **42** 250–66

ESRI 2009 *ArcGIS 9.3* (Redlands, CA: ESRI)

Evans T P and Moran E F 2002 Spatial integration of social and biophysical factors related to landcover change *Popul. Dev. Rev.* **28** 165–86

Evans T P, VanWey L K and Moran E F 2005 Human-environment research, spatially explicit data analysis, and geographic information systems *Seeing the Forest and the Trees: Human-Environment Interactions in Forest Ecosystems* ed E F Moran and E Ostrom (Cambridge, MA: MIT Press) pp 23–56

Heleniak T 2001 Demographic change in the Russian Far East *The Russian Far East and Pacific Asia: Unfulfilled Potential* ed M J Bradshaw (Richmond: Curzon) pp 127–53

Hitztaler S K 2003 Transformations in post-Soviet Kamchatka: a study of the relationship between resources and changing human populations *MS Thesis* University of Michigan, Ann Arbor

Hitztaler S K 2004 The relationship between resources and human migration patterns in central Kamchatka during the post-Soviet period *Popul. Environ.* **25** 355–75

Hitztaler S K 2010 An ethnography of landscape: exploring the dynamics among people, forests, and resource use in post-Soviet central Kamchatka *Dissertation* University of Michigan, Ann Arbor

Huntington H P 2000 Using traditional ecological knowledge in science: methods and applications *Ecol. Appl.* **10** 1270–4

Ioffe G, Nefedova T and De Beurs K 2012 Land abandonment in Russia: a case study of two regions *Eurasian Geogr. Econ.* **53** 527–49

Ioffe G, Nefedova T and Zaslavsky I 2004 From spatial continuity to fragmentation: the case of Russian farming *Hum. Ecol.* **32** 257–59

Jarvis A, Reuter H I, Nelson A and Guevara E 2008 *Hole-Filled SRTM for the Globe Version 4* (available from the CGIAR-CSI SRTM 90m Database, http://srtm.csi.cgiar.org)

Kabanov N E 1963 Typi listvennicnykh lesov Kamchatski Lesa Kamchatki i Ikh Lesokhozaystvennoe Znachenie ed N E Kabanov (Moscow: USSR Academy of Sciences)

Krankina O N, Sun G, Shugart H H, Kasischke E, Kharuk V I, Muller D 2012 Effects of institutional changes on land use: state-command to market-driven economies in post-Soviet Siberia *Land Use Policy* **29** 1360–70

Krestov P V 2003 Forest vegetation of easternmost Russia (Russian Far East) *Forest Vegetation of Northeast Asia* ed J Kolbек et al (Dordrecht: Kluwer) pp 123–38

Krestov P V 2003 Forest vegetation of easternmost Russia (Russian Far East) *Forest Vegetation of Northeast Asia* ed J Kolbек et al (Dordrecht: Kluwer) pp 93–180

Lambin E F 2003 Linking socioeconomic and remote sensing data at the community or at the household level: two case studies from Africa *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS* ed J Fox et al (Boston, MA: Kluwer) pp 223–40

Lambin E F and Geist H 2006 *Land-Use and Land-Cover Change: Local Processes and Global Impacts* (New York: Springer)

Leica Geosystems 2009 *ERDAS IMAGINE* 9.2 (Norcross, GA: Leica Geosystems)

Lerman Z, Serova E and Zyvagintsev D 2008 Diversification of rural incomes and non-farm rural employment: survey evidence from Russia *J. Peasant Stud.* **35** 60–79

Lerman Z and Shagina N 2007 Land policies and agricultural land markets in Russia *Land Use Policy* **24** 14–23

Lillesand T, Kiefer R and Chipman J 2007 *Remote Sensing and Image Interpretation* (New York: Wiley)

Liu J G, Ouyang Z, Taylor W W, Groop R, Tan K C and Zhang H M 1999 A framework for evaluating the effects of human factors on wildlife habitat: the case of giant pandas *Conserv. Biol.* **13** 1360–70

Liu J G et al 2007 Complexity of coupled human and natural systems *Science* **317** 1513–6

Metzo K 2001 Adapting capitalism: household plots, forest resources, and moonlighting in post-Soviet Siberia *Geojournal* **54** 549–56

Mikhailova N 2002 Social and economic differentiation in the Russian Far East *Russia’s Far East: A Region at Risk* ed J Thornton and C E Ziegler (Seattle: National Bureau of Asian Research in Association with University of Washington Press) pp 85–115

Newell J 2004 *The Russian Far East* (Tokyo: Friends of the Earth)

Nyerges A E and Green G M 2000 The ethnography of landscape: GIS and remote sensing in the study of forest change in West African Guinea savanna *Ann. Anthropol.* **102** 271–89

O’Brien D J, Wegren S K and Patsiorkovsky V V 2005 Marketization and community in post-Soviet Russian villages *Rural Sociol.* **70** 188–207

Olson D M, Dinerstein E, Wikramanayake E D, Burgess N D, Powell G V N and Underwood E C 2001 Terrestrial ecoregions of the world: a new map of life on earth *Bioscience* **51** 933–8

Pallot J and Moran D 2000 Surviving the margins in post-Soviet Russia: forestry villages in northern Perm’ *Oblast Post-Sov. Geogr. Econ.* **41** 341–64

Pallot J and Nefedova T 2003 Geographical differentiation in household plot production in rural Russia *Eurasian Geogr. Econ.* **44** 40–64

Pallot J and Nefedova T 2007 *Russia’s Unknown Agriculture: Household Production in Post-Socialist Rural Russia* (Oxford: Oxford University Press)

Peterson L K, Bergen K M, Brown D G, Vashchuk L and Blam Y 2009 Forested land-cover patterns and trends over changing forest management eras in the Siberian Baikal region *Forest Ecol. Manag.* **257** 911–22

Pickup F and White A 2003 Livelihoods in postcommunist Russia: urban/rural comparisons *Work Employ. Soc.* **17** 419–34

Prishchepov A V, Radeloff V C, Baumann M, Kuemmerle T and Muller D 2012 Effects of institutional changes on land use: agricultural land abandonment during the transition from state-command to market-driven economies in post-Soviet Eastern Europe *Environ. Res. Lett.* **7** 024021

Rindfuss R R, Prasartkul P, Walsh S J, Entwistle B, Sawangdee Y and Vogler J B 2003a Household-parcel linkages in Nang Rong, Thailand: challenges of large samples *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS* ed J Fox et al (Boston, MA: Kluwer) pp 131–72

Rindfuss R R, Walsh S J, Mishra V, Fox J and Dolcemascolo G P 2003b Linking household and remotely sensed data: methodological and practical problems *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS* ed J Fox et al (Boston, MA: Kluwer) pp 1–30

Rindfuss R R, Walsh S J, Turner B L, Moran E F and Entwistle B 2004 Linking pixels and people *Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth’s Surface* ed G Gutman et al (Dordrecht: Kluwer) pp 379–94
Roskartografia 2001 Topographic Map Series 1: 100,000 (Moscow: Roskartografia)

Seeth H T, Chachnov S, Surinov A and Von Braun J 1998 Russian poverty: muddling through economic transition with garden plots World Dev. 26 1611–24

Smith E A 1983 Anthropological applications of optimal foraging theory: a critical review Curr. Anthropol. 24 625–51

Southworth C 2006 The dacha debate: household agriculture and labor markets in post-socialist Russia Rural Sociol. 71 451–78

SPSS (PASW Statistics) 2009 SPSS Version 17.0.3 (Chicago, IL: IBM)

Turner B L, Moran E and Rindfuss R 2004 Integrated land-change science and its relevance to the human sciences Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth’s Surface ed G Gutman et al (Dordrecht: Kluwer) pp 431–48

Walsh S J, Bilsborrow R E, McGregor S J, Frizzelle B G, Messina J P, Pan W K, Crews-Meyer K A, Taff G N and Baquero F 2003 Integration of longitudinal surveys, remote sensing time series, and spatial analyses: approaches for linking people and place People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS ed J Fox et al (Boston, MA: Kluwer) pp 91–130

Winterhalder B and Smith E A 2000 Analyzing adaptive strategies: human behavioral ecology at twenty-five Evol. Anthropol. 9 51–72

Wright C K, de Beurs K M and Henebry G M 2012 Combined analysis of land cover change and NDVI trends in the Northern Eurasian grain belt Front. Earth Sci. 6 177–87

Yamin-Pasternak S 2008 A means of survival, a marker of feasts: mushrooms in the Russian Far East Ethnology 47 95–107

Yudina V F, Belonogova T V, Kolupaeva K G, Muratov Y M and Bogdanova G A (ed) 1986 Brusnika (Lingonberry): Morfologiya i Anatomiya, Fitotsenoticheskaya Priurochnost’, Urozhainost’, Khranenie i Pererabotka, Khimicheskii Sostav Yagod (Moscow: Lesnaya Promyshlennost’).