A Landcover Map of the Russian Far-East Based on NOAA AVHRR Satellite Data

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From

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Introduction

We have made a 1 km resolution landcover map of 600,000 km^2 of far eastern Russia including all of Primorski Kray and portions of Kharbarovsk Kray east of 130^0 E. long. and south of 55^0 latitude. This region includes the cities of Kharbarovsk and Vladivostok and most areas in this region east of the Amur River as well as portions of China near Lake Khanka. The labeling of the land cover was based on an existing Russian forest cover map and newly digitized maps on hand here. This new landcover map's primary purpose is to define areas of forest versus non-forest and areas of recent landcover disturbance. We anticipate that WWF will use this data with their own data and data from the IUCN Redbooks to define habitats and range maps for threatened animal species and their remaining habitat. Only in unusual circumstances, however, can small changes in land cover (anything less than a few km by a few km) be determined with data of this resolution.

Objectives

The objective of this work was to create a 1-km resolution land cover map of the region of the Far Eastern Siberia based on NOAA AVHRR data available here. Labeling of land cover classes depended upon the Russian 1990 Forest Cover Map (Garsia 1990), the analyst's experience with AVHRR data and Russian data sources.

Data

The primary data for this map were:

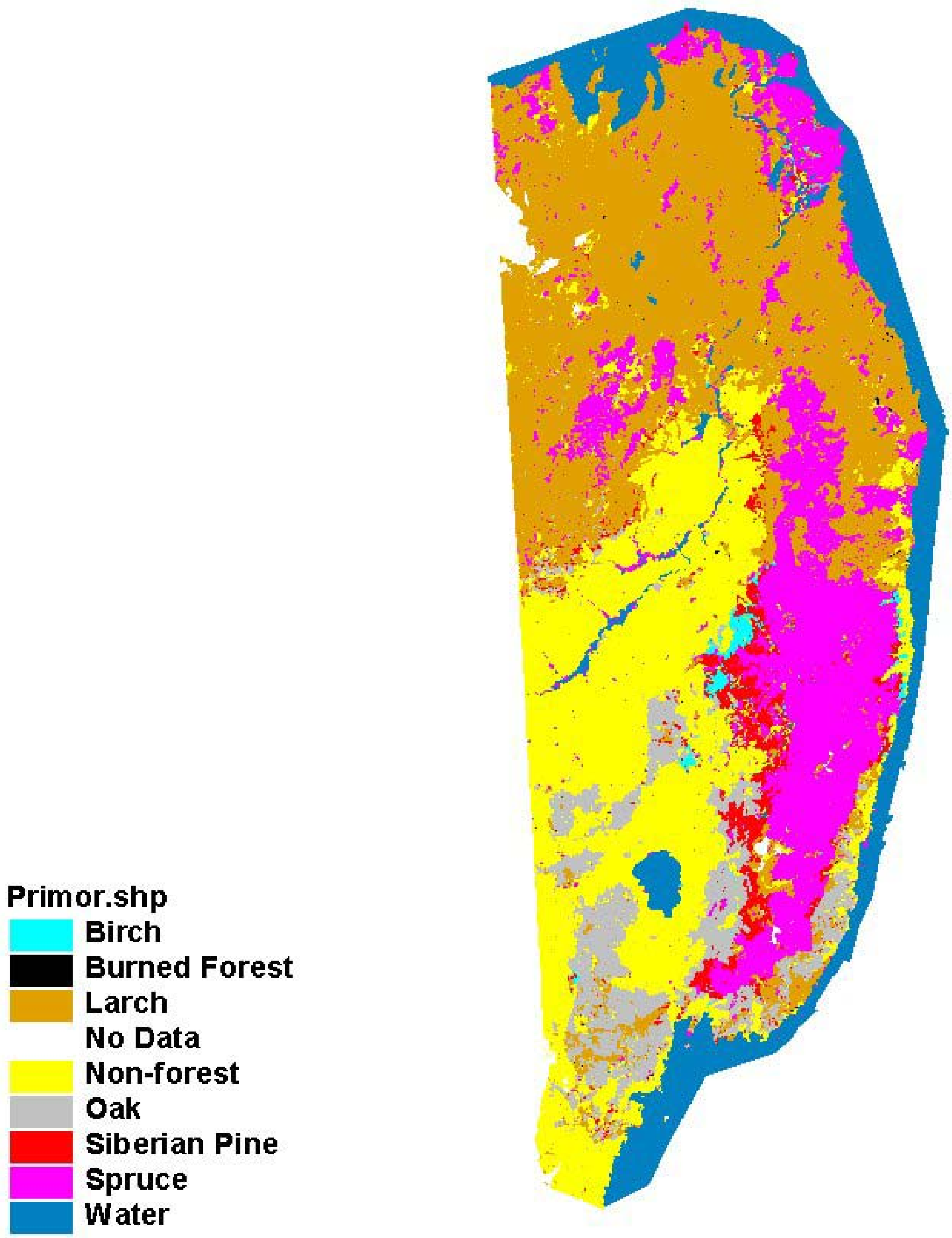
- Six scenes of NOAA AVHRR LAC (Local Area Coverage) 1 km resolution satellite data from 1990,
- The 1990 Soviet Forest Cover map (1:2,500,000 scale) digitized here,
- One Landsat TM image covering an area near Vladivostok (made available through a NASA Data Grant).

From the fives scenes of NOAA AVHRR imagery we were able to construct a largely cloud-free mosaic of the region of the project.

We would hope from this project that there would be a publishable paper. WWF might arrange for the final printing of the map. We are responsible for providing the final product in a digital format. We can, however, produce here 8.5" x 11" color prints, which can be assembled into a draft copy of the landcover map or HP Inkjet plotter output up to 32" wide.

Landcover of

Primorye and S. Khabarovsk Regions



Projects Steps

1. Data Acquisition

We purchased from the USGS EROS Data Center (EDC) five different scenes of NOAA AVHRR LAC data of the region. Data was purchased with funding from both private and federal sources for use in other projects.

This data includes imagery from the following dates:

May 15, 1990

This data was geometrically registered here through the selection of ground control points and rubber sheeting. Forty-seven ground control points were selected.

All remaining dates were geometrically registered and radiometrically corrected at the EROS Data Center. These dates include:

July 18, 1990 Satellite 1
July 18, 1990 Satellite 2
July 19, 1990
August 15, 1990
August 17,1990

2. Assembling all LAC data onto a computer work station:

The primary task in assembling the data into a useable format was the co-registration of all data to a common map projection. We have chosen Lambert Azimuthal equal area projection of all our Russian work.

3. Cloud Removal

Clouds prevent satellite data interpretation. Cloud removal was done manually by digitizing the major cloud formations with a mouse and then cutting them out. Minor clouds were left in the unclassified data and were eliminated later after the classification of the data. As clouds tend to have unique spectral signatures being both very bright and very cold they usually classify easily.

4. Radiometric correction on all LAC data which was done, as mentioned previously at the EROS data center

5. Classify the satellite data by clustering all LAC data.

All data, after cloud removal, was classified using the ERDAS Isodata algorithm (ERDAS, 1991). Each date of imagery was done separately. This algorithm is an iterative clustering program that is not spatially dependent. Each date or scene was clustered into 50 different classes and signatures for all classes were extracted. The signatures developed were then used to perform the actual classification of pixels with a typical nearest neighbor supervised classification. All signatures were examined to evaluate vegetation vigor indexes and for extreme brightness or temperature information.

6. Data conversion of the digital Forest Cover Map

The Russian Forest Cover Map covers all the former Soviet Union at the scale of 1:2,500,000. There are 16 individual map sheets. Our region of interest is covered by two map sheets (Numbers 12 and 16). The major or dominant forest types and major inland water bodies are described as polygons by the map. It is not clear whether the map describes the majority tree species or the majority economic tree species. In general, Russians we have consulted indicate that the map describes the majority tree species. If this were not the case and the majority of economic tree species were defined by the map, there would be a systematic under-representation of "soft" deciduous forest species such as birch and aspen. The map defines discreet polygons and, generally, assigns one tree species to that polygon. This is rarely the case in nature, however. Mixed polygons, those having more than one tree species, exist on the map in only one case, mixed spruce-fir.

Like most boreal forests, the age of these forests and the species present are largely a function of the region's fire history. Natural and man-made fires are common and their intensity often determines the type of forest that regenerates. Birch, aspen, larch, and Siberian pine are first in succession after fires and are followed by spruce and fir. Generally, as one proceeds north, larch dominates and forms almost pure but sparse forests or woodlands. The dominant tree species of the region are, respectively, larch (Larix. spp.), spruce (Picea siberica and obovata), birch (Betula pendula and other spp.), Siberian pine (Pinus siberica) also known as "kedr" or cedar, Oak (Quercus mongolica?), spruce with fir (Abies siberica) mix, Pinus Pumila, and aspen (Populus tremuloides). See Table 1.

Table 1

Landcover of the region based on the 1990 Forest Cover Map of (Garsia 1990) digitized at WHRC. This includes a portion of northeastern China.

# Type	Sq. Km	Percent Area	Cover Type
2	111,438	17.53 %	Spruce
3	74	0.01 %	Fir
4	22,058	3.47 %	Spruce/Fir Mix
5	175,436	27.59 %	Larch
6	45,706	7.19 %	Siberian Pine
7	1,014	0.16 %	Juniper
8	35,025	5.51 %	Oak
10	96	0.02 %	Hornbeam
11	415	0.07 %	Sub-Arc Birch
13	45,786	7.20 %	Birch
14	3,042	0.48 %	Aspen
15	127,553	20.06 %	Non-Forest
16	10,214	1.61 %	Water
18	794	0.12 %	Sparse Spruce
20	256	0.04 %	Sparse Spruce/fir
21	3,049	0.48 %	Sparse Larch
22	297	0.05 %	Sparse Siberian Pine
23	1,189	0.19 %	Sparse Oak
24	1,290	0.20 %	Sparse Birch
25	89	0.01 %	Sparse Birch 2
26	197	0.03 %	Sparse Aspen
27	19,107	3.01 %	Burned Forest
28	431	0.07 %	Cut Over Areas
30	14,443	2.27 %	Outcrops/Stones
31	3,146	0.49 %	Lime
32	53	0.01 %	Salt tolerant sp.
33	5,534	0.87 %	Other Wood
37	240	0.04 %	Birch Shrub
38	7,864	1.24 %	Pinus Pumila
Totals	635,836	100 %	

7. Co-registration of digital Forest Cover Map with the satellite data

To determine the common areas of the Forest Cover map and the satellite- based map the two digital products required that same geometric or map projection and coordinate system.

8. Labeling of LAC classes using Forest Cover Map

Each satellite- based class was labeled according to the majority class of the Forest Cover Map. For instance if the satellite class was composed of, according to the Forest Cover Map, 70 % Spruce, 20 % Pine and 10% water, the class would be labeled Spruce.

We could have just as easily provided two labels for each class with the dominant and second most common class providing the labels. Almost all land cover classes would then be mixed classes. In the case described here, that would mean that the classe label would be Spruce-Pine. Doing this would double the number of landcover classes for the region.

9. Mosaicking of the classified LAC data

We produced four maps from this effort. The differences between the maps were a result of the order in which the dates of the classified satellite data were assembled or mosaicked together. The mosaicking of the data is order-dependent - that is, the final classified satellite image added writes-over all previous classified data except where the final image has no coverage. Think of it as stacking randomly oriented pieces of Swiss cheese where in most locations the last piece added will dominate the appearance of the cheese pile when looking down on it from above. But, in a few locations you can see all the way through the pile and these would be areas for which we have no usable data. In a few other locations you can see down two layers or three layers and so forth. Satellite data added earlier in the stitching process will show in the final map only if the last date added has no data for that region. Therefore the final map is a mosaic of dates but is dominated by the final date added. From this, it is easy to see that the order of stitching can have a major effect upon the appearance of the final map.

Development of Results

11. Development of numerical data from satellite classifications.

Digital summaries of each of the mosaicked classifications allow us to determine the area assigned to each forest cover type or to water or to non-forest.

12. Inter-comparison of results with other data.

To perform inter-comparisons with Russian source data we removed land cover classifications in China done during this effort and also removed ocean classified as water. Consequently, in Table 2 we are comparing the Russian Forest Cover Map with the satellite based map.

Table 2. Results of landcover classification of satellite data of the Russian region of study area. Values rounded to 100s of km^2. The Russian Forest Cover map is by Garsia (1990).

	Garsia, 1990 km^2	WHRC Test 2 km^2	Diff. from Garsia in %	WHRC Test 3 km^2	Diff. from Garsia in %	WHRC Test 4 km^2	Diff. from Garsia in %
Coniferous	175,200	210,500	+20.1	222,400	+26.9	223,300	+27.4
Deciduous	88,300	49,300	-44.2	46,900	- 46.9	46,900	-46.9
Larch	138,900	121,100	-12.8	121,300	-12.7	125,500	-9.6
Total Forest	402,400	380,900	-5.3	390,600	-2.9	395,700	-1.6
Non-Forest	147,200	161,700	+9.9	151,400	+.2.9	151,400	+2.9
Water (inland)	10,200	4,200	-58.8	4,800	-52.9	5,200	-49.4
Total Land	549,500	542,600	-1.3	542,000	-1.4	547,100	-0.4

The first column in this table are the estimates of land cover from the Garsia (1990) Russian (Soviet) Forest Cover Map that we digitized here. We have combined all deciduous forest categories and all coniferous forest categories (see Table 1) for the purposes of inter-comparison and we have kept larch as a separate category. In the columns labeled WHRC we show our estimate of landcover based on three different combinations (Test 2, Test 3, Test 4) of the satellite data available to us here. The column labeled "Difference..." show the percentage change with the estimates based on Garsia (1990).

Conclusions

We have a much lower estimate of inland or interior water than the Russian Forest Cover Map of Garsia (1990). This probably results from our inability to determine smaller bodies of water with the satellite data.

We show considerably more coniferous forest than seen in the Garsia (1990) Forest Cover Map.

We show a significant decline in the amount of larch forest compared with the Garsia (1990) Forest Cover Map. This decline has occurred in the northern parts of the region.

We show a significant decline in the amount of deciduous forest compared with the Garsia (1990) Forest Cover Map. This decline has occurred in the southern part of the region, which is the more heavily populated part of the region.

We show a small but consistent decline in overall forest area compared with the Forest Cover Map of Garsia (1990).

We show an increase in the amount of non-forest area compared with the Forest Cover Map of Garsia (1990).

Our estimate of total land area is essentially the same as the Forest Cover Map of Garsia (1990).

Discussion

We know little about how the Russian forest map was constructed and, although the publication date is 1990, it undoubtedly represents forests at some even earlier point in time. Therefore, even if the map and our classification based on the satellite data were perfect, we would expect to see some changes due to the time differences between the map and satellite data.

By itself, the scale of the map (1:2,500,000) imposes a limitation on the accuracy of the map. At this scale, the black lines defining the polygons are 2.5 km wide. Therefore, a typical polygon of 1 cm^2 on the map, which nominally covers 625 km^2, has a boundary of covering 100 km^2. This implies a possible error of 100/625 or 16%. This error would be smaller for larger polygons and larger for smaller polygons but would also be a function of the polygon's area to perimeter ratio.

The techniques used here, choosing the majority landcover class for labeling, tend to reduce smaller, scattered, and more unique land cover classes and emphasize the larger and more contiguous classes.

References

Garsia, M. G. (ed.) 1990. "Forests of the USSR", Scale 1:2,500,000 All-Union State Planning-Research Institute "Sojuzgiprolezhoz" GUGK, Moscow, USSR.

Erdas, 1991. ERDAS Field Guide, 2nd Edition, Ver 7.5, ERDAS Inc., Atlanta, 294 pp.

Future

The possibility exists of obtaining more no or low cost 1 km data from colleagues at NASA Langley, the EROS Data Center or NOAA and more high resolution LANDSAT TM MSS or SPOT data but we do not propose to do this now and it appears to be outside the scope of the current project. We did not have the data here to look over time (over years) with 1 km LAC data.

We would also produce a high-resolution (30 to 80 m) land cover map of the region near Rudnaya Pristan with labeling based on existing Russian maps and newly digitized maps which we have here. We would use the digital imagery described in # 2 with the 180 by 180 km Landsat TM data. The high-resolution data would allow us to define specific regions of logging (clear-cut and selective), roads, burn scars, mines etc. for the date of the imagery. Also, this type of data is commonly used to "tune" 1 km resolution data so that information gained at the higher levels of resolution can be scaled up but as we only have one date of TM data the tuning could only occur in the area ENE of Vladivostok.

For the 1 km product we could overlay digital road networks based on the digital chart of the world (DCW) and digital data of the region held by WWF.

Table 3. Digital Map Labeling Convention

Spruce	102
Larch	105
Siberian Pine	106
Oak	108
Birch	113
Non-forest	115
Water	116
Burned forest	127
No Data or Outside Study Area	0