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Fixed categories in a portable landscape: the causes and consequences of land-cover categorization

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Abstract. In this paper I explore both the causes and the effects of defining land-cover categories for the mapping of landscapes. Utilizing a participatory remote sensing technique in a case example from Rajasthan, India, I demonstrate that local and expert characterizations of the environment are qualitatively and quantitatively divergent. Satellite imagery, I therefore conclude, is not an impartial tool for the settlement of debates about land cover but is instead the result of prior debates about the character of nature. Moreover, such imagery acts as a force in the transformation of the environment; by fixing certain interpretations of the environment and forcing certain forms of management, technology changes on the land through a process of reverse adaptation. I conclude, therefore, that bureaucratic efforts at mechanical objectivity serve to institutionalize and therefore create measurable, quantifiable, and aggressive land covers through the practice of ecological modernization.

The nature and direction of environmental change are debated at the global, regional, and local levels. Long-maintained arguments for continental-scale land-cover changes are increasingly called into question in international circles (Binns, 1990; Fairhead and Leach, 1998) while local actors too, including bureaucrats, citizens, and environmental experts, continue to debate the degradation and recovery of important landscapes. Satellite imagery and other forms of remotely sensed data have been introduced into such debates to settle them, and to clarify the trajectory of environmental change with reference to hard facts.

Yet satellite imagery, rather than reducing the contentiousness of landscape-change claims, actually reinforces it. One satellite image, for example, which I recently took on a circuitous tour through a small town in India, evoked myriad interpretations. Going door-to-door and visiting along the way a number of local inhabitants, I observed a wide range of interpretations of the same hard data. Foresters poured over the image and traced their fingers along the edges of a rugged line of hills, suggesting the cover there represented evidence for reforestation. Farmers pointed to bare soils and showed denuded areas where forest had disappeared on the edge of villages. A retired forester decried the disappearance of tree cover along the forest fringe. A worker at a local advocacy organization for pastoralists identified large swaths of grassland lost to trees. The same fragile satellite image supported the tremendous weight of many interpretations, some of them complementary, others contradictory.

Such a range of interpretations should be in no way surprising. Landscapes are constantly read and reread in the practice of daily life, and the plurality of interpretations underlines the instability of any single reading (Barnes and Duncan, 1992). This is especially true in a world of proliferating landscape images, including traditional maps as well as air photography and satellite imagery. The mobility of these technologies and technological artifacts, evidenced by the presence of satellite images and GIS platforms in remote villages, puts more landscapes into the hands of more people. Landscapes are therefore highly *portable* and are increasingly mobile with every technological innovation in geographic science.

Even so, in the act of bounding, naming, and describing important patterns in a satellite image, including deforestation, reforestation, and desiccation, observers must set the categories of analysis to convey the urgency of real-world phenomena. Land-cover changes in these complex landscapes can take form only by *fixing* the categories of their interpretation; one must identify forest in order to map deforestation, for example.

But where competing accounts of what constitutes the categories of landscape exist, the fixing of those categories is an inherently political exercise. Definitions of 'forest' or 'grassland' are contentious at best and can, in many cases, serve as sources and locations for conflict. The state and its cartographic servants have historically held the monopoly on fixing definitive accounts of landscape and have usually had the upper hand in defining land-cover change as a result. Efforts in countermapping and other participatory methods in GIS (Harris and Weiner, 1998; Peluso, 1995; Weiner et al, 1995) have drawn attention to the wide range of competing accounts of what the landscape is, and how it might be changing. By creating competing maps, traditionally disempowered populations seize the terms of cartographic debate for defining and controlling the landscape. But more than this, by setting the categories of analysis, such mapping acts to direct the future of landscape management and land-cover change.

The questions that emerge in the wake of this better understanding of the relationship between geography and epistemology are threefold. First, because maps of land cover derived from local knowledge are rarely analyzed through controlled comparison, it remains unclear whether the landscape accounts of environmental professionals and other groups are consistently divergent (Robbins, 2000). Do they differ in a uniform fashion, and along what axes of difference? Second, the degree to which emergent technologies, such as remote sensing and GIS, have affected public and professional landscape conceptions is also underexplored. Has the advent of these portable technologies changed the perceptual apparatus of development professionals and local people? Finally, the relationship between these emergent technologies and actual landscape change is also largely unknown. Has the measurement of the landscape through remote platforms led to new kinds of landscapes?

Using a participatory mapping technique, I here explore these questions, examining not only the causes of clashing land-use classifications, but also their effects. The method employed satellite imagery to map the competing landscape conceptions of professional foresters and local producers in a case study from the region surrounding the Kumbhalgarh Wildlife Sanctuary in Rajasthan, India. Starting from land-cover definitions elicited from photograph identification and interviews with herders, farmers, and forestry officials, I conducted a classification of the same multispectral data sets twice, based on the divergent views of expert foresters and local producers. The resulting digital images were used to compare the differing categories of land cover both qualitatively, in terms of their meaning, and quantitatively, in terms of their spatial coverage and location.

The analysis suggests that competing maps of the region share common ground in some areas of the landscape but are marked by profound contradictions in others. In particular, the willingness of foresters to accept as 'forest', the expanding savanna scrublands dominated by invasive species, stands in marked contrast to the views of locals, who often see such landscapes as degraded. In the process, incentives are formed for professional forestry to reproduce these landscapes of invasives. Thus, an eco-managerial bureaucratic imaginary at Kumbhalgarh enables the parameters of remotely sensed data to reengineer the landscape.

More generally, the results of the study underline the fact that satellite imagery is not an impartial tool for the settlement of debates about land cover but is instead the result of prior debates about the character of nature. Moreover, imagery is itself a force in the transformation of the environment. By empowering and fixing certain interpretations and interpretive practices, the technology changes the land through a process of *reverse adaptation* (Veregin, 1995; Winner, 1977). I conclude, therefore, following Porter (1995, page 700), that the pursuit of objectivity in modern scientific and bureaucratic communities, driven by challenges to the legitimacy of state expert power, has led to the increasing promulgation of portable technologies and the hegemonic imposition of state-fixed categories through the practice of ecological modernization.

Categories in a complex landscape

The arrival of satellite imagery to help interpret landscape change is nowhere more happily anticipated than in the Godwar region of Rajasthan, adjacent to the Kumbhalgarh Wildlife Reserve, flanking the Aravalli hills of southern Pali district (figure 1). The area is a semiarid farming belt adjacent to a hilly deciduous forest dominated by perennially green deciduous xerophytic tree species. The predominant

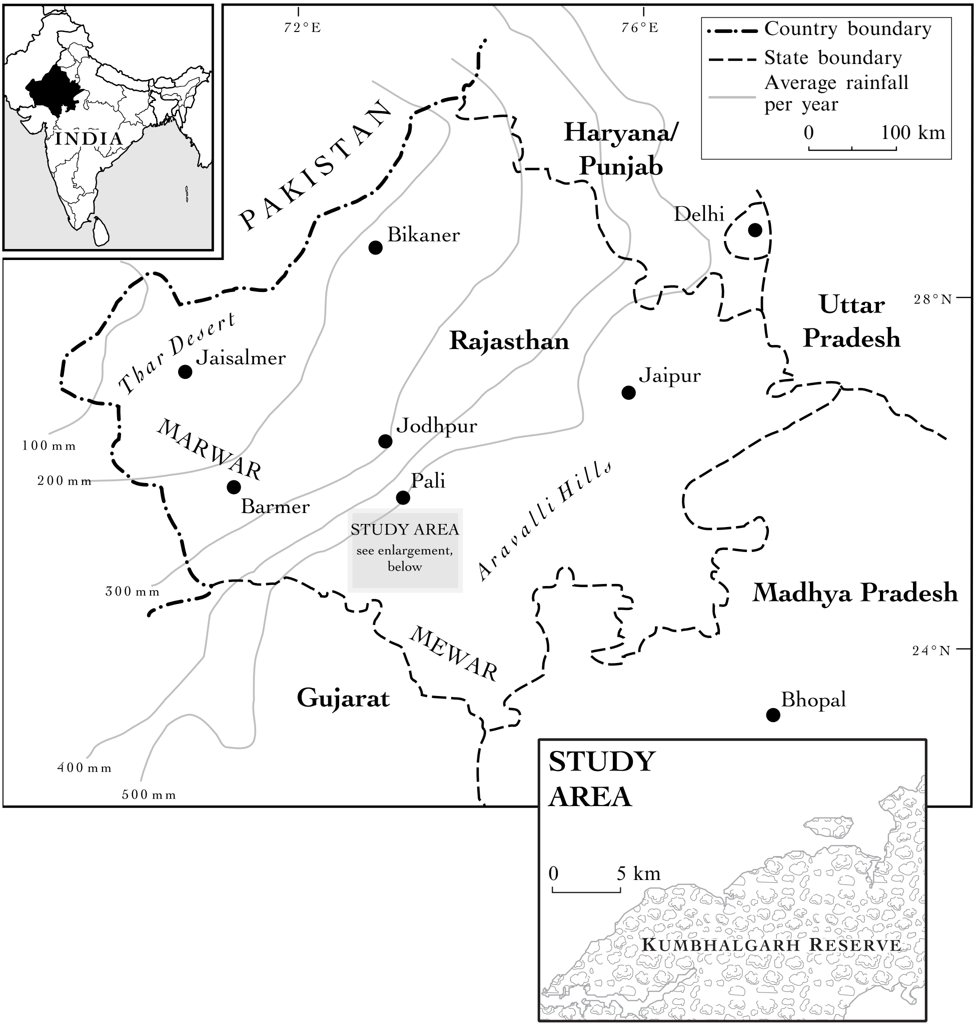

Figure 1. The Kumbhalgarh Wildlife Sanctuary, located on the spine of the Aravalli Hills in southern Rajasthan, India.

mode of subsistence is a mixed agropastoral strategy that depends both upon intensified production techniques and upon a heavy use of the wild resources of forest and fallow land. As a result foresters and local nongovernmental organisations both clamor for comprehensive data on the state of land resources, especially forest, because sweeping policy changes in recent decades have made spatial and temporal management decisions imperative. Within the Rajasthan Forest Act of 1955, which empowered the enclosure of the Kumbhalgarh Reserve, there is a great deal of discretionary room for varying management strategies and practices. Foresters and locals must negotiate when and where to enclose sections of the forest from grazing, who should be allowed access to forest resources, and where to focus Forest Department efforts at environmental decline and amelioration.

In particular, it is crucial to determine exactly how much forest there is, where the forest is, and whether it is in expansion or decline, because the limited resources of the forest-management bureaucracy must be spread over a wide array of management tasks. The topographical and ecological complexity of the region makes such an assessment difficult. The reserve, though not overlarge, is thickly wooded and difficult to penetrate. The adjacent plains are covered with a mixed savanna that supplies timber, fodder, and fuel resources for villagers but which varies tremendously in species mix, density, and rates of decline and recovery. So too, there is disagreement about the rate and location of forest-cover change. Local people insist that forest cover is in decline but the location of that change and its driving causes vary from individual to individual and group to group (Robbins, 2000). Foresters, on the other hand, largely agree that forest decline has halted in the last decade and that recovery is in evidence in some places.

Thus, almost all parties greet the prospect of satellite-image information and mapping tools with interest. Foresters are sure that it will verify the claims that forest cover is stable or expanding. Locals believe it will reveal the decline in key resources. Problems remain, however, for implementing satellite-image analysis to address these questions. Specifically, the image-classification process requires that definitions for key features of the landscape be known before the fact either to form training sites for supervised image classification or to group reflectance clusters in unsupervised classification (Robbins, 2001). The complex landscape vocabulary of local people and its divergence from that of professional foresters make establishing these claims categories difficult, however. Where definitions of land-cover types differ between foresters and locals, as is often the case, it is necessary either to choose one interpretation over the other or to accept divergent classifications of reflectance 'reality'. Of the two options, the latter method, drawing as it does on participatory GIS techniques (Weiner et al, 1995) and countermapping (Peluso, 1995), provides a better window into the role and effect of remote sensing technology on the landscape.

Method: participatory classification technique

Fieldwork was conducted during November and December of 1999. SPOT image satellite scenes of the study region were obtained for the month of January in both 1986 and 1999. Within the image, 27 spatially stratified sites were selected to represent a range of vegetation mixes and land uses. These were ground-truthed and photographed and the ground cover at each location was recorded. Photographs of each of these sites were given to 68 local producers and 9 foresters for identification. The sample was purposive, representing producers across a range of caste (*jati*) communities and land endowments, and included nine women. Participants were asked to identify the photographs, providing whatever land-cover category they believed each photograph represented. Responses varied greatly between foresters and locals and also within the local group itself, especially between pastoral and agricultural producers.(1) For the purposes of this study, aimed at exploring relationships between professional and local knowledge, each site was given two identification categories, the first based on the category given to the site by a majority of locals, and the second based on the identification used by professional foresters.(2)

The study sites were then digitized into polygons with IDRISI image-processing software. Two sets of reflectance signatures were produced from the two sets of sites defined by locals and foresters, by using 1999 reflectance characteristics of the study site groups in the green, red, near, and middle infrared bands. The 1999 image was then classified twice, by using the two sets of signatures in a maximum likelihood classification, assuming equal prior probability of all classes and excluding the least likely 5% of all pixels from classification (Lillesand and Kiefer, 1994; Richards, 1993).

Put plainly, in supervised classification an entire region is classified by using the reflectance characteristics of sample areas known by the analyst on the ground to belong to certain classes. This is a standard technique in image classification, which allows identification and categorization of unknown areas based upon the characteristics of known ones. In this case, however, the 'known' study sites were aggregated and named based upon the divergent definitions given by locals and foresters in their identification of photographs. Of six pictures of mixed scrub, for example, foresters might identify three as 'forest'. The reflectance characteristics of the three areas corresponding to those photographs would then be used to generalize the 'forest' coverage for the entire region. The resulting map would show the distribution of all areas that foresters would likely identify as 'forest'. Locals, on the other hand, might identify three entirely different photographs as *junglat* (or forest) or one of those photographs, in addition to two or three others that foresters identified as something else. The local image would show a very different distribution of junglat, therefore, representing only those areas that locals would consider as forest.

The resulting images were evaluated for the areal coverage of each class and were cross-tabulated against one another to quantify the relative differences between categorical systems (Eastman et al, 1991). This technique derives a kappa index, which reflects the level of spatial agreement between pairs of corresponding categories. Where the quantity and distribution of a locally defined land cover are similar to that of a forester-defined coverage, the kappa approaches 1.00 (Carstensen, 1987; Rosenfield and Fitzpatrick-Lins, 1986). Further processing cross-tabulated the land-cover images with images created using 1986 and 1999 data including coverages of: (1) cover to *Prosopis juliflora* scrub, (2) normalized difference vegetation index, and (3) change in vegetative cover. The second cross-tabulations derived a Cramer's V-statistic (following Ott et al, 1983), which shows the overall degree of agreement between these images and those classified using local and forester categories.

Competing categories of land cover

Tables 1 and 2 (see over) show the range of categories reported for the study sites. The differences between local and professional categories are notable in several regards. First, locals reported a much larger number of categories overall, producing 19 in total. Foresters produced only 7 categories. This may be an artifact of the smaller sample of foresters interviewed relative to nonforesters, but also reflects the relatively more

(1) Variations in local knowledge tend to fall along classed and gendered axes of social difference (Schroeder, 1999). These disappear in this method of aggregation, but are examined more fully in Robbins (2000).

(2) This analysis follows the method described and preliminarily deployed in Robbins (2001), which describes the epistemological underpinnings of a "participatory classification technique".

Table 1. Producer categories for study-site identification.

Use or cover name	Characteristics
Farm or *erat*	Agricultural land of 50 bighas or more, generally cultivated twice a year, with irrigation and high-energy inputs.
Aakariya or *medan*	The gathering place for cattle in the mornings and evenings and from where they are taken into hills by the village herder.
Abadi	Village or town land.
Baghicha	A garden with fruit trees.
Bakhar	A broken terrain of large rocks and high elevation.
Banjar	Characterized by (1) a thin soil layer and (2) salinity. Land may become banjar from degradation, denuding, or the invasion of *Prosopis juliflora*.
Gocher	Land belonging to the village, covered in grasses and shrubs. Used for grazing.
Jangal	Dense forest cover consisting of species including Dhav, Palas, Khumbat, Kair, Saress, and Karaya.
Jordh	Fertile land, in a single crop (*shaven sakh*), currently in short fallow.
Kharas	Compacted soils. Hard, unfertile land, usually light colored. This land has gone barren through erosion or invasion by juliflora.
Kharva	Land in the delta areas of small rivulets. Cannot be cultivated but is characterized by scrub cover.
Kheti	Brown soil, fertile—generally double cropped or currently in crop.
Magara	Hilly and rocky forest area, with Dhav, Khumbat, and Salar in abundance.
Partal	Water-eroded land, usually as a result of sheet erosion. Sometimes used in grazing where the land supports annual grasses and shrubs.
Reliya ki zamin	Bottom land in fertile drainage.
Reveni	(Revenue) land which cannot be cropped, usually covered in grasses and occasional shrubs, especially Deshi Babul, Aak, and Khejri.
Simada	Single cropped (*jordh*) land, currently in long fallow used for grazing.
Tutal zamin	Barren land with rolling or broken terrain, usually in the vicinity of or flanking the hills.
Vala	Rivulets draining from hills, between 5 and 10 feet in width, which meet larger watercourses outside the forest.

Table 2. Forester categories for study-site identification.

Use or cover name	Characteristics
Agricultural or *khetadari*	All land in current cultivation.
Fallow	All agricultural land not currently in production.
Forest	Areas with tree canopy, not suitable for cultivation.
Nadi	A stream or river basin, currently bare.
Orchard	Area of tree cropping.
Revenue waste	Land suitable for cultivation but currently underutilized or land incapable of supporting agriculture; currently in fallow.
Town or *abadi*	Urban or developed village land; housing, streets.

uniform typology of land covers institutionalized through forester experience and training. Foresters, particularly those in the middle ranks, describe with pride their training in forestry schools such as the Forest Research Institute and Colleges in Dehra Dun and their retraining in workshops occasionally held in this or other official centers. At these sites, categories are established and reinforced and the naming of landscapes is institutionalized.

For foresters without such formal training, repeated daily interaction drives and unifies category sets; to succeed socially as a forester requires the use and deployment of uniform forester knowledge. This, in turn, reflects the self-organizing tendencies of the forestry institution itself. As Douglas explains, "institutions survive by harnessing all information processes to the task of establishing themselves. The instituted community blocks personal curiosity, organizes public memory, and heroically imposes certainty and uncertainty" (1986, page 102). For organized forestry in Rajasthan, the survival of the bureaucracy relies upon establishing and demonstrating its expert power through language. And in turn, the daily practices of the individual forester, like the naming of the landscape, are tied economically and ideologically "to the perpetuation of the apparatus and the persistence of its rationally organized domination" (Weber, 1978, page 988). Institutions do the naming for individuals; state forestry does the categorizing for foresters.

Second, forester categories were notable in that they were predominately given in English, whereas local categories were provided in either Hindi (as taught in state grade-schools) or Marwari (a local dialect). We see in the specific categories of state forestry, the strong influence of colonial and postcolonial knowledge. Specifically, the categories of foresters reflect the categories of the census system, relict in the region from the imposition of survey techniques of the British Political Agent when the Rajputana states were put under colonial residency in the 19th century (Rajputana-Gazetteers, 1908). Most prominently, the colonial-era category of 'waste' land persists from that time, and continues to include all land 'suitable for cultivation' that is not already under the plow. These lands are valuable resource areas for locals who use them for grazing, and fodder and food collection (Brara, 1992). The instrumental character of forester categories is therefore notable, if no way surprising.

Local categories are notable in that they show an extreme sensitivity to processes of ecological succession and change. By distinguishing length of fallow, reduction in productivity, and density of growth, locally defined categories are not only spatial, they are *temporal*, and reflect sophisticated notions of ecogenic and athropogenic change. The length of fallowing time, for example, distinguishes *jordh* and *simada* lands, and *banjar* and *partal* land are distinguished by varying forces of degradation and change. This mirrors the characteristics of indigenous land-cover classifications more generally, which commonly recognize "continua, successions, tendencies, and cycles" (Ellen, 1982, page 223).

Competing conceptions of forest cover

For the purposes of further comparison, these landscape typologies were collapsed into four more general groups, as shown in table 3. All landscape categories that were based on tree cover were collapsed into the *junglat*/forest category. All agricultural categories were collapsed into *kheti*/cultivated category. All fallow or grazing categories were collapsed into the category of *akad*/grassy. All categories signifying degraded, bare, or urban, were collapsed together into *banjar*/bare. The images produced through this recategorization were then cross-tabulated to assess the degree of coincidence (table 4). The areal extent of each category is shown, as is the degree of intercategory agreement, expressed as a kappa value (following Carstensen, 1987; Eastman et al, 1991).

Table 3. Collapse of categories for comparison.

Producer category	Includes	Forester category	Includes
Junglat	*jangal*; *kharva*; *magara*	Forest	forest
Kheti	'farm'; *erat*; *baghicha*; *kheti*	Cultivated	agricultural; *khetadari*; orchard
Gav/banjar	*aakariya*; *bakhar*; *banjar*; *kharas*; *medan*; *partal*; *tutal zamin*; *vala*	Urban/bare	*abadi*; *nadi*; town
Akad/gocher	*gocher*; *jordh*; *reliya ki zamin*; *reveni*; *simada*	Grassy/fallow	fallow; revenue waste

Table 4. Category coverage compared.

Category	Producer coverage	Forester coverage	Agreement κ
Junglat or Forest	328.5	444.1	0.34
Kheti or Cultivated	111.2	103.3	0.97
Banjar or Bare	91.1	34.6	0.63
Gocher or Fallow	132.3	100.9	0.86

The spatial coverage of kheti land matches that of cultivated land extremely well, suggesting a high level of agreement between foresters and locals about what constitutes a field and where fields are located. There is slightly less overall agreement between producers' akad/gocher land and foresters' grassy/fallow land, though these two seem to coincide overall. The long fallow and open grazing lands of the region seem to have some categorical unity in both the minds of professionals and of agro-pastoral locals. Agreement over what constitutes bare, degraded, or urban land is far poorer, and there is extremely poor agreement between the junglat and forest categories. Producers recognize a larger coverage of degraded or bare land than do foresters, while foresters see considerably more forest than locals. It is evident that locals do not similarly name areas called forest by foresters. Breaking down the forester category coverage based on its definition by locals (table 5), we see 263 km^2 of forest cover, as defined by foresters, that locals would indeed call junglat or some comparable name suggesting or highlighting tree cover. Yet another 181 km^2, or more than 40% of the total, is differently identified. A small proportion of this area (around 8%) is identified as akad or kheti land, but a far larger area, almost one third, is identified as either banjar (degraded or waste land) or is simply left unclassified in local definitions.

Figure 2 shows the spatial distribution of agreement and disagreement in the forest category. The southeast portion of the image, where the wildlife sanctuary is located, is dominated by 'shared' coverage that both foresters and locals would identify as tree covered, forest, or junglat. This is the old swath of deciduous forest that crowns the

Table 5. Producer definitions for areas identified as forest by professional foresters.

Producer category	Coverage (km^2)	Proportion (%)
Junglat	263.27	59.28
Kheti	10.162	2.29
Gav/banjar	62.74	14.13
Akad/gocher	25.52	5.75
Not classified	82.44	18.56
Total	444.14	100

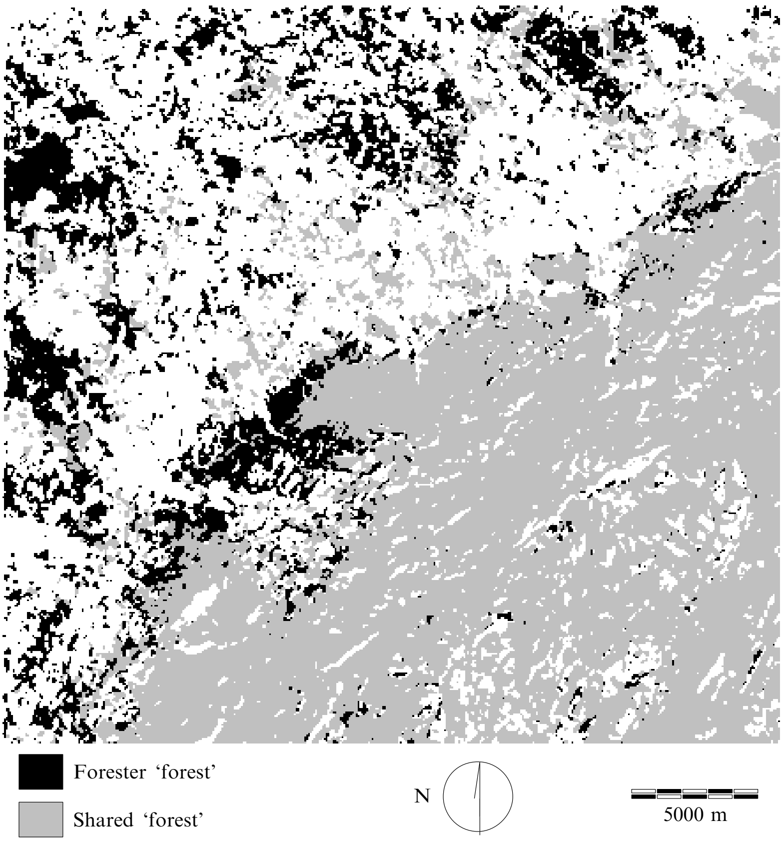

Figure 2. Comparing forest-category coverage.

hilly areas running southwest – northeast across the region and which forms the geographical southernmost boundary of the Marwar region of Rajasthan. A unitary cultural and historical imaginary includes this kind of hilly tree cover as forest both for producers and for foresters. The northwestern part of the image, representing the flat lowlands historically covered in savanna scrub, is dominated by land that foresters would define as forest but that local people would not. These areas, producers prefer to call banjar (degraded) or to leave unclassified. But what is this cover?

Competing perceptions as competing ecologies

If we examine forest and junglat areas on the ground, it is evident that the variation in perception and definition reflects differences in tree-species cover at these locations. Those areas defined by foresters as forest, which local producers do not, include areas where there has been a steady influx of the invasive species *Prosopis juliflora*. Juliflora, or Mexican mesquite, is an aggressive and highly successful tree, owing to its drought tolerance, its germination-inhibiting leaf-litter (Al-Humaid and Warrag, 1998; Noor et al, 1995), and its quick-forming umbrella canopy that grows laterally outwards in a few short years.

To confirm the correlation between forester-defined forest and juliflora, an image showing the areas that *only* foresters defined as forest (based upon that shown in figure 2) was cross-tabulated against a second image, which shows the scrub coverage emergent since 1986. This second image, developed through supervised classification and isodata clustering of the same SPOT data, shows thorn forest areas dominated by

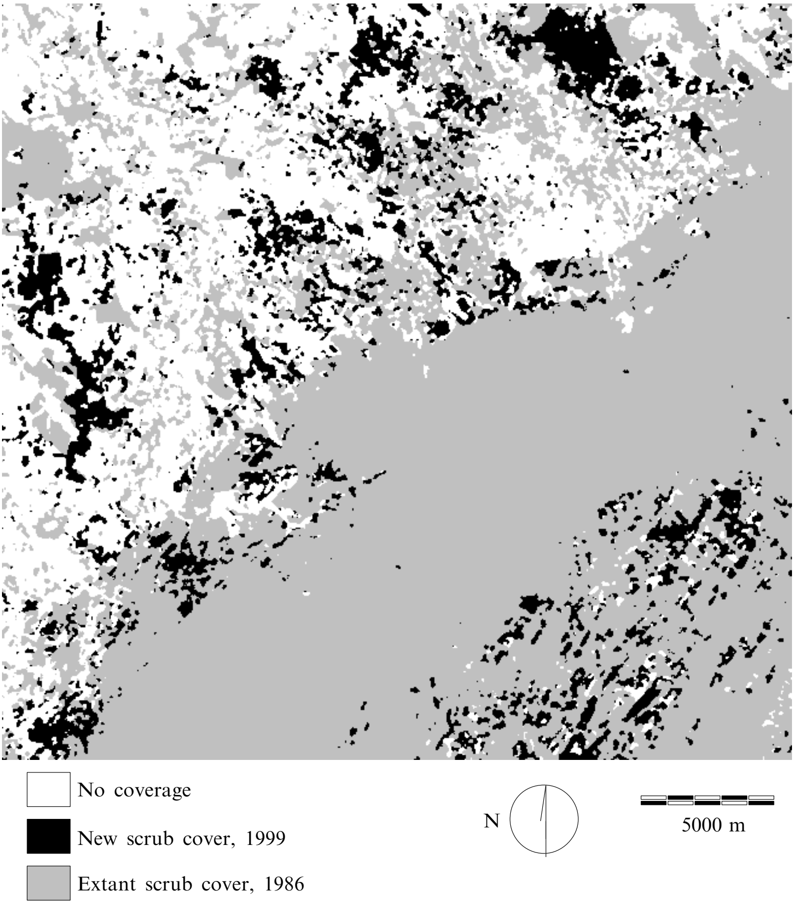

Figure 3. Emergent scrub canopy 1986–99.

juliflora that have emerged in the thirteen-year period since 1986 (figure 3). A resulting Cramer's V of 0.404 reflects a statistically significant relationship between foresters' forest and the invasive tree species; a significant proportion of the juliflora coverage are areas that foresters would call forest which local producers would not.

To assess further and confirm that variation in vegetative cover between forester and producer 'forests', the two perception images were next used to extract normalized difference vegetation index (NDVI) figure averages in each perceptual category for both the years 1986 and 1999. NDVI values are the normalized ratio of infrared to red reflectance at a location so that high NDVI values reflect relatively high levels of vegetation coverage. NDVI images were created by using SPOT image data for the same area in both years. The NDVI figures for each of the two defined coverages of

Table 6. Normalized difference vegetation index (NDVI) values for competing views of forest.

	Producer *junglat* coverage	Forester forest coverage	Difference
Mean 1999 NDVI	0.164	0.142	0.022
Mean 1986 NDVI	0.122	0.116	0.006
Change 1986–99	−0.042	−0.026	0.016

forest (producer and forester) are shown in table 6. Mean NDVI values for forester forests in 1999 were lower than those of producer junglat coverage in 1999; areas defined by locals are thicker in overall biomass than those recognized by foresters. Whereas this is also true for the year 1986; the areas defined by foresters are 'greener' than those understood by locals. Whereas this is also true for the year 1986, the difference in the 'greenness' of forester and locally defined forests is greater in 1999 than in 1986; forester-defined forest areas are relatively greener now compared with their local counterparts than they were in 1986. Finally, the decline in overall greenness between 1986 and 1999 in the area, owing at least in part to the lower rainfall in the later period, is more severe in locally defined forests than in those defined by foresters.

The relatively faster developing 'greenness' of forester-defined forest areas, reflected in differential NDVI values, demonstrates the swift growth of the juliflora tree, which though imported from the Americas at the turn of the century, was unseen in this region before the mid-1980s; these are *new* forests. Put simply, those areas that foresters identify as forest but local producers do not, are most often areas dominated by a recent invasive species, one that grows quickly and appears very green when viewed remotely.

As suggested by the previous categorical analysis, local producers generally reject this coverage as forest, either giving it no name or describing it as banjar or wasteland. As Pema Ram Divasi, an elder of the pastoral Raika community stated emphatically when asked whether a thick stand of juliflora trees represented a forest: "That is not a true forest. A forest has Dhav, Kair, and Palas. This has no name." For local people, the spread of this species is a problem owing to its low fodder value, inferior quality as a wood fuel, and concomitant contribution to grassland decline. They do not see the spread of juliflora as the spread of forest but, instead, often see it as a form, or at least a sign, of land degradation (figure 4).

Most foresters, on the other hand, seem to recognize the cover as forest, even though this new coverage of forest is expanding into grasslands, far outside the range of the Forest Department enclosures, and even though it does not resemble indigenous forest coverage. The reasons for the embrace of this species and landscape

Figure 4. *Prosopis juliflora* coverage in the village of Latara, 1999. This village pasture (*gocher*) was reportedly productive in the last twenty years but has been overrun entirely by mesquite.

are complex, but point to the relationship between forestry practice, remote sensing, and the bureaucratic incentives of institutionalized knowledge.

Discussion: portability, legitimacy, and objectivity

It might be argued that the motivation for bureaucratic support of juliflora is based in the overall industrial orientation of Indian forestry. Certainly democratic modernization of the Indian nation-state in the postindependence era enabled the growth of a powerful environmental bureaucracy that, like other bureaucratic structures, was created in service of emergent capitalism and state industrialization (Das, 1998; Gadgil and Guha, 1992; 1995). But state forestry was also directed towards the emancipatory social-welfare goals of the Nehruvian socialist state. For environmental bureaucracies in India, therefore, as in the rest of the world, the instrumentalist mandate for industrial exploitation has often vied against a more populist conservation obligation and an emphasis on local use-rights and access. The rise of social forestry initiatives in the last twenty years, for example, has shifted bureaucratic attention towards issues of livelihood and local use even while plantation-mode industrial forestry remains a significant mission (Corbridge and Jewitt, 1997; Gadgil and Guha, 1992). According to Weber, these simultaneous and contradictory developments in the bureaucracy were perhaps inevitable; the quantitative growth in the size of bureaucracies and the qualitative growth in the range of bureaucratic tasks were both necessitated by the twin goals of technical industrial advance and social democratization (Beetham, 1996; Weber, 1978). The aggressive and overwhelming support for juliflora certainly mirrors the Forest Department's efforts in industrial forestry in other regions, where historical enthusiasm for modern 'scientific' forestry has persisted to encourage contemporary plantation monoculture and disciplinary forestry (Gadgil and Guha, 1995; Jewitt, 1995).

Forestry in southern Rajasthan is notably noninstrumental, however, and reflects social welfare goals rather than cash-crop capitalization. Juliflora has shown little real commercial value, so that any simple explanation of bureaucratic behavior in the favor of *Prosopis juliflora* as an industrial product is hard to support. The Forest Department indeed extols the species largely for its power in 'mitigating poverty' by supplying wood to avert a fuel crisis in the desert (Dass et al, 1988; Muthana, 1988).

In the case of Rajasthani land cover, a more robust explanation must go beyond simple instrumental logics and examine the social structure of environmental state agencies, where categorization, measurement, and performance evaluation together determine the tendencies and possibilities of ecological transformation (Dove, 1994; 1995). The politics of categorization are especially complex in the Indian bureaucracy, where 'objective' standards are fundamental to the social structure of expertise.

If we follow Porter (1995), it is possible to see in the Kumbhalgarh case, a struggle for objectivity, where the 'private' knowledges of foresters is leveraged into 'public' knowledge by the establishment and promulgation of categories that are remotely sensed, universal, and quantifiable. By tracing the incentives and methods of these environmental practices to the social institutions of expert bureaucracy, then, a clearer explanation emerges of the relationship between remotely sensed data and juliflora trees, and between categories and ecology more generally.

Pursuing objectivity through mechanical and quantitative means

Measures, Kula (1986) noted, are an "attribute of authority", over which vying powers struggle for control and standardization. Similarly, the control of categorical systems, like those for Indian land cover, represent a traditional area where state authorities seek the monopoly power to name. But more than this, scientific and bureaucratic communities like the Indian Forest Service are impelled, by pressures imposed from without, towards specific practices, including pursuit of 'mechanical' objectivity, quantification, and acceptance of universal analytical categories.

Mechanical objectivity represents replicable and rule-bound methods of practice. Distinct from 'disciplinary' objectivity, represented by expert discretionary knowledge, mechanical objectivity becomes the normal practice when social and political pressures raise questions about the legitimacy of professional practitioners. As Porter demonstrates using the example of the US Army Corps of Engineers, 'mechanically objective' econometric analysis is often incorporated into defensive bureaucracies apparently to distance them from the 'play of politics' represented by the 'disciplinary objectivity' of expertise. Quantified and normalized data and proof reinforce the legitimacy of a bureaucracy that is otherwise suspected of politically instrumental decisionmaking, and so establishes objectivity and trust in bureaucratic action. This pursuit of objectivity also hinges on the ability of differing communities (scientists, bureaucrats) to turn their 'private' knowledges—those created and exercised locally (that is, in the laboratory)—into 'public' knowledge, that can be deployed in a range of contexts. To do so, Porter observes, quantification and normalization are essential tools.

Quantification and species choice

This drive for objectivity is reflected in Forest Department behavior in two ways. First, the system of incentives for promotion, and hierarchical ordering of forestry bureaucracy are generally structured to reward advancement through rational and 'objective' meritocratic methods; maintaining budgets, meeting schedules, and defending office autonomy are all rewarded through promotion. The use of these and other apparently objective measures of success shows the degree to which mechanical objectivity for selection is required to overcome the perceived caste and class differences that might otherwise dominate advancement. Postindependence modernization in India brought with it a variety of such political mechanisms to reduce the normative discretionary power of class and caste (Rudolph and Rudolph, 1967; Singer, 1972; Srinivas, 1987).

Forestry in Rajasthan, as a result, evaluates and rewards its success largely on the basis of objective indices of success: coverage figures and survival rates of trees (Robbins, 1998; Sargent and Bass, 1992). The central statistical measures for plantation-species selection are, therefore, population survival percentages and average heights; forestry means putting into the ground trees that will survive and become tall.

In keeping with this philosophy, experimental plant science in the Central Arid Zone Research Institute in Jodphur Rajasthan has been dedicated to selecting species that meet these requirements. As a result, more than 250 exotic species were imported and evaluated over a twenty-five year time span, including 112 *Eucalyptus* species, 68 *Acacia* species, and 82 'miscellaneous' species (Dass et al, 1988). Of these, *Prosopis juliflora* stands out repeatedly in the literature and in discussions with foresters as the tree of choice for arid areas.

As Hocking observes, "P. juliflora is a very aggressive tree, competes strongly for soil moisture and is difficult to eradicate once estalbished" (1993, page 281). In discussing the species with foresters it became clear that these were viewed as the very merits of the tree and that forester preference for the species was in part tied directly to the incentive structure of survival and advancement. As one forester reminded me, "you cannot be promoted if the trees do not survive." Thus, while the tree has its opponents within the bureaucracy, it is for the most part accepted without controversy. Its expansion and survival on the ground are a goal of forestry and these trees, therefore, represent forests.

Objectivity and portable technology

Second, the urge to mechanical objectivity is reinforced through the engagements of the Forest Department with the diverse local populations with whom it is in contact and over whom it must attempt to enforce control. These populations, as demonstrated above, have their own secure and well-established set of private knowledges, the local categories of ground cover known to producers. The bureaucracy's legitimacy comes to be predicated, in reaction, on their ability to produce public knowledge, the more universal, portable, measurable, and quantifiable land covers of state census. No matter how poorly such categories reflect the diversity of local ecologies, their establishment is necessary for state servants.

As a result, the rise to prominence of juliflora is tied to the emergence of remote sensing from aerial photography and satellite-image platforms, especially in state-sponsored projects that form an increasing part of India's social forestry mandate. Budget allotment for forestry activities in Rajasthan between 1994 and 1997 expanded by 255%, increasing by US $15 million, while the total area under forest department control expanded by only 3.6%, with the net acquisition of around 1100 km^2 of land. These budget increases have therefore served less to enclose land than to increase plantation and expand and professionalize the bureaucracy, train staff, and implement new technologies.

In particular, air photography and remote sensing have long been targeted for incorporation into management and are increasingly used to map areas of forest cover and track progress in afforestation and reforestation (Aggarwal, 1988; Hooja, 1984). In the area of wastelands development, there has also been a growth in inventory and mapping activity. Between 1985 and 1990, wastelands development in Rajasthan received 390 million rupees (around US $10 million) from USAID and the World Bank. Much of this funding went directly into plantation efforts, bringing 120 000 ha in the state under direct management but, like traditional forestry efforts, these projects were predicated on mapping efforts conducted in collaboration with the National Remote Sensing Agency and the Survey of India. These endeavor to map wastelands and identify areas for activity and progress made by the Department of Forestry and other agencies within the Ministry of Environment (Government of India Ministry of Environment and Forests, 1990). Proposals for ongoing mapping activities continue to appeal for national and international funding and emphasize categorization as a prerequisite to action, insisting that to "improve the resource base of these [arid] lands, it is necessary to i) categorize the different types of wastelands, ii) map their distribution pattern, and iii) identify their characteristics" (CAZRI, 1998, page 3).

Though few of these tools are yet available to the local forest managers who actually oversee forestry plantation and administration, the overall awareness of the implications of these forms of spatial data is commonly understood throughout the bureaucracy. The connection between development, mapping, and remote sensing is an increasing part of the daily vocabulary of forestry. Specifically, foresters generally report that the rapid spread of the *Angrezi Babul* (*Prosopis juliflora*) tree can be seen from the air, and that this transformation stands as a testimony to the success of the Forest Department's public mission (Robbins, 2000). This point of view, which champions the species by way of its *observable* canopy, was consistently reiterated in interviews with forest guards, range officers, and more elite managers. As Hoeschele (2000) observes, GIS land-cover analysis tends to favor observable land cover over the complexities of locally defined land use.

Thus, as foresters adopt remote sensing techniques or at least become increasingly aware of them, the bureaucratic measurement of success—coverage of land in something called forest—increasingly demands an understanding of forest as a dense lateral green canopy that is spectrally discernable, or at least that can easily be observed from the air. Such a definition matches the characteristics of the monocultural stands of juliflora. Having defined this form of canopy cover as forest, foresters largely ignore or tolerate it, or in any event, do not define it as a problem. These techno-discursive feedbacks in the establishment of juliflora-dominated landscapes are summarized in figure 5, which shows the relationship between the technologies of remote sensing, the ecological tendencies of *Prosopis juliflora*, and the discursive construction of forests in the landscape. Introduced technology creates the parameters within which bureaucratic incentives are formed; juliflora is overlooked as benign because the greening of the landscape, visible with the introduction of new technology, matches the incentives of the agency. The technological and categorical structure of bureaucratic forestry sets and reinforces the direction of environmental change.

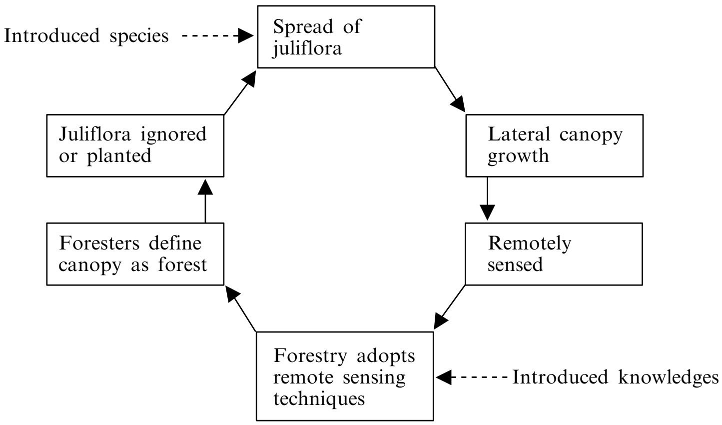

Figure 5. Techno-discursive feedbacks.

Technological agency and landscape

Ultimately then, satellite images act in at least two ways not otherwise noted in celebratory discussions of the power of the tool (Liverman et al, 1998). First, following Latour (1987), we can say that the satellite appears as the arbiter for a dispute about land cover but, in fact, actually acts to justify an already settled dispute about the nature of that landscape. Second, following Veregin (1995) and Winner (1977), we can say that the satellite image serves as a force for reverse adaptation, where existing landscapes are reengineered to suit technical means, rather than the other way around.

In the first case, the satellite image serves a complex double roll in the interpretation of landscapes. The image appears as a 'natural' artifact of reflectance that settles the question: "how much forest is there?" But as we have seen, the image is created only after a prior argument is settled: "what are forests?" Once we have decided that mesquite monoculture constitutes a forest landscape, then controlled and statistically reliable methods of generalization from multiband data show that a wide and expanding swath of forest exists on the plains. Thus, satellite images are not only the cause of the settlement of a scientific controversy ("how much forest is there?") but are in fact themselves the consequence of a dispute settlement ("what are forests") (Latour, 1987). By appearing as the natural arbiter of the former dispute, the latter one disappears altogether and landscapes are written as though there was no disagreement over the nature of the land. The satellite image, ultimately therefore, enforces an interpretation of the landscape rather than arbitrating between competing claims.

In the second case, satellite and image-processing GIS technology have inherent tendencies for interpreting and defining space, and so act to alter the landscape in particular ways. In this case, the monocultural stands of juliflora form coherent pixels and easily reveal themselves to remotely sensed technologies. As a result (and owing to its overall persistence and survival), the species comes to represent forests for foresters, who then act or fail to act so that such forest covers spread. The technology, therefore, is not neutral. Its optics cause it to participate in landscape change in specific ways and landscapes are adapted to suit the observational parameters of the tool. This reverse adaptation of geography by technology attests to the unexpected consequences of fixing the landscape based on portable technologies (Veregin, 1995; Winner, 1977). The satellite image is, therefore, a social agent of environmental change, serving as an ally in disputes over the nature of the landscape while actually acting to help create new incentives that remake the land in its own form of measure.

Institutions, categories, and ecological modernization

The case of Kumbhalgarh, in this way, informs a more fundamental problem in naming, measuring, and controlling the landscape. The definition of forest land cover by Indian bureaucrats is very much like other cases around the world, including the definition of "old growth forest" in the US Pacific Northwest (Norheim, 1999) or the establishment of "ecosystem boundaries" in Toronto suburbs (Keil and Graham, 1998). In a comparable case from US forestry, forest coverage expanded as a result of changes in accounting techniques, which were themselves obligated by congressional mandates for conservation (Hays, 1987; Porter, 1995). In these cases, the establishment of apparently objective techniques for defining nature depends on bureaucratic and institutional systems of categorization (Bowker and Star, 2000), often rooted in the highly portable technologies of remote sensing and mapping. These, in turn, lend momentum to certain forms of environmental change.

Such a process is further enabled under the expanding global prevalence of "ecological modernization" (Hajer, 1997). Ecological modernization holds that, because human understandings of ecological problems are increasingly "science led", then "solutions equally depend upon the mobilization of scientific expertise and corporate technological skills embedded within a rational (state-led) process of political-economic decision-making" (Harvey, 1996, pages 177 – 178). This discourse increasingly pervades the Indian forestry bureaucracy where foresters, like their counterparts all around the world, are trained in a form of technical eco-managerialism, which naturalizes the use of such technologies (Luke, 1999). Thus, as ecological modernization increasingly holds a hegemonic position as master narrative of environmental decline and recovery, technology becomes increasingly and dangerously "autonomous" (Winner, 1977) with its bias and partiality hidden beneath layers of naturalized technical practice.

In sum, I have argued that the arrival of remotely sensed data, while extremely promising for inventory and analysis in complex landscapes, brings its own limitations and biases emphasizing horizontality and reflectivity in landscapes. Coupled with bureaucratic incentives of self-reproduction and an increasingly eco-managerial culture of modernization in environmental governance, these tendencies are set loose to reproduce landscapes in their own form, green canopies with dubious human or ecosystem value. The measurement of these resulting landscapes through the very tools of their transformation naturalizes the resulting ecologies and erases the history of intervention from which they arise. Only by backtracking to the production of such images, and showing the contentiousness of the categories that undergird the deployment of imagery, can the socially embedded nature of landscape analysis be rendered clear.

I have not argued here that satellite imagery and air photography are bad tools for the analysis and management of natural systems. These instruments continue to be some of the most promising for exploring landscape change, and assessing human–environmental action across scale (Liverman et al, 1998). Nor have I suggested that Indian forestry bureaucracy, charged as it is with a staggeringly difficult social–environmental mission, is a malicious agency or inherently ill suited to land management. The state will continue to be a major player in South Asian social ecology, for better and for worse, and the historic lack of engagement with state agencies on the part of Indian environmentalists is likely self-defeating (Rangan, 1997). Rather, I have argued that the encounter of remote sensing with bureaucratic authority under conditions of ecological modernization is one of which analysts and activists must be wary.

While we will inevitably and increasingly depend on remotely sensed data to measure the nature and direction of ecological change, therefore, we cannot depend on such imagery to adjudicate fundamental disputes over the nature of the environment that are prerequisite to such measurements. And though we must use the tool to measure the rate and extent of environmental change, we must acknowledge that the employment of the satellite itself serves as an agent of environmental transformation. Living with such contradictions is prerequisite to future geographic science.

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