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Mapping Marijuana Cultivation Sites and Water Storage in the Redwood Creek Watershed, Southern Humboldt County

Cristina Bauss
Humboldt State University, cib15@humboldt.edu

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Learn more about the author in Alumni Highlights on Page 74.

Since the late 1960s, the Emerald Triangle—Humboldt, Mendocino, and Trinity counties—has been one of the nation's hotbeds of marijuana cultivation. Begun by the counterculture's "back-to-the-land" movement, over the last five decades what began as a black-market phenomenon has flowered into a billion-dollar industry. In 2007 the US Department of Justice estimated that California produced between 60 and 70 percent of all the marijuana consumed in the United States (Carah et al. 2015, 1), and in 2014 the state accounted for 49 percent of all legal sales in the country (ArcView Market Research 2015). That same year, the Drug Enforcement Administration eradicated 2.68 million plants in California (DEA 2015, 72); untold numbers remained, and the value of the illegal market has been virtually impossible to quantify. Marijuana is reputedly one of the state's top cash crops, but it is not listed in annual reports released by state and federal agriculture agencies.

Marijuana's complex legal status and lack of regulatory oversight have ensured that until recently, its environmental impacts have also remained largely unquantified. As more states have legalized or decriminalized it, however, more researchers have taken an interest in assessing the environmental issues attributable to unregulated cultivation. On both public and private lands, these include dangers to wildlife exposed to numerous agricultural toxins (Gabriel et al. 2012, 12; Harkinson 2014; Peeples 2013), sediment delivery to streams from road and home construction and grading for outdoor gardens (Short 2011, 110), and destruction of wildlife habitat due to stream diversions (Barringer 2013). On public lands, trespass grows have become perilous for both land managers and members of the public who inadvertently stumble onto cultivation sites; in 2013, they accounted for 72 percent of all outdoor plants seized in California (Harkinson, Brownell, and Lurie 2014). Meanwhile, for decades marijuana has also been cultivated on private lands without the oversight mandated for other agricultural products.

Effective regulation of California's marijuana industry demands a quantifiable understanding of the existing scope of cultivation, and the adequacy of water storage, on private lands that have long been devoted to a de facto commercial industry. The first objective of this research is to review the historical context of the Emerald Triangle. The second

Figure 1. Location of the Redwood Creek watershed, in southern Humboldt County. Detailed view, upper right inset; view within California, lower left inset (sources: USGS Earth Explorer, County of Humboldt, California Department of Forestry and Fire Protection; map by author).

is to provide a case study of the Redwood Creek watershed (Figure 1)—one of the first places where the back-to-the-land movement became entrenched, and exemplary of numerous areas where ranching and timber extraction have largely given way to unregulated, commercial-scale marijuana cultivation.

Historical Background

In the century and a half since European-Americans began permanently settling the North Coast, its landscape has been fundamentally changed by land privatization (i.e., ranching and farming), commercial fishing, and commercial timber extraction. The latter has been arguably the most environmentally destructive, with only 4 percent of the old-growth redwood forest that once dominated the Pacific coast from central California to southern Oregon remaining (National Park Service 2015). The devastation wrought on the land altered the region's rivers as well. Sedimentation from grading, road development, and erosion has left many waterways unsuitable for salmon, one of the North Coast's keystone species (McKee 2004, 13; Short 2011, 113).

In the wake of the post-World War II construction boom that felled numerous stands of virgin redwood and Douglas fir (Easthouse 2002), a new threat emerged. Because many ranchlands and timberlands had been so degraded they were no longer commercially viable, they were subdivided into smaller parcels that were sold at very low prices. Numerous such parcels were purchased by "back-to-the-landers" for whom marijuana cultivation became a chief source of income (Torgoff 2004, 281). As a group, they thought of themselves as responsible stewards of the land (Scott-Goforth 2013, Salmonid Restoration Federation 2013). By the early 1980s, however, the 1960s ideals of the first generation of back-to-the-landers had begun to give way to "greed grows" that exacted a heavy toll on an already devastated landscape.

In 1983 the Campaign Against Marijuana Planting (CAMP) was established, a multi-agency task force whose stated objectives included the reduction of marijuana availability through plant eradication, arrest and prosecution of marijuana cultivators and traffickers, reduction of marijuana-related environmental impact on public lands, and reduction of "associated criminal activity" in areas where cultivation occurred (CAMP 1983, 11). Raids on outdoor cultivation sites quickly led to many growers moving their operations indoors, to both greenhouses and permanent structures. Ironically, this enabled them to cultivate much more, and more potent, marijuana: as many as six crops can be grown indoors in a single year, and by controlling light, humidity, and temperature, an indoor cultivator can clone plants with higher levels of delta-9-tetrahydrocannabinol (THC), the physiologically active component in cannabis (Martyny et al. 2013, 622).

In 1996 California became the first state to legalize the use of medical marijuana through passage of Proposition 215, the Compassionate Use Act (Bauer et al. 2015, 1-2; Carah et al. 2015, 4). Seeking to cash in on an economic boom driven by legal marijuana sales, a new wave of migrants began pouring into the North Coast, and unemployed local timber workers began cultivating marijuana as well (Barringer 2013; Harkinson 2014). Industrial-scale marijuana farms—some with tens of thousands of plants—now dominate

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many parts of the Emerald Triangle, on public, tribal, and private lands (Barringer 2013). Paradoxically, the very land subdivisions that facilitated the back-to-the-land movement now facilitate another wave of environmental destruction. As Boston University professor Anne G. Short explains, "The slow but ongoing land-use transition from timber and ranch lands to more rural residential and amenity-oriented development...can be linked to an increased risk of sediment delivery to local streams and the continued degradation of habitat for salmonids" (2013, 122). Local creeks are often sucked dry for marijuana cultivation, and the widespread use of agricultural toxins has adversely affected numerous species including the Pacific fisher (Martes pennanti pacifica), a member of the weasel family that inhabits forests from northern California to Washington (Gabriel et al. 2012, 1).

Unregulated Marijuana Cultivation and the Environment

The complex legal status of marijuana poses unique challenges for researchers trying to quantify its environmental impacts, and for policymakers seeking to develop long-term solutions to industry-related problems (Carah et al. 2015, 4-5). To date, only one peer-reviewed study has attempted to quantify the extent of marijuana cultivation within specific watersheds (Bauer et al. 2015). For Redwood Creek, the results were alarming: according to Bauer et al., "estimated water demand for marijuana cultivation is 36-173% of the annual seven-day low flow" (2015, 13). A review of several other studies reveals additional impacts, all germane to commercial agriculture. They include the following.

Land-Use Changes. In a 2011 study focusing on subdivided lands in Humboldt and Mendocino counties, the researcher found that landowners who are engaged in timber and ranching are far more knowledgeable about best management practices (BMPs) than residential, vacation, and other landowners who tend to be more recent transplants to rural areas, and whose private properties are not as strictly regulated as commercial properties (Short 2011, 121).

Sedimentation. Sedimentation is one of the key problems associated with rural residential development, agricultural terracing, and road construction; not only does it degrade habitat for salmonids and amphibians, but it is also associated with habitat fragmentation and edge effects that in turn impact species composition—often favoring nonnative over native species (Short 2011, 109-113).

Rodenticide Use. A significant environmental concern associated with both commercial agriculture and residential gardening is the widespread use of second-generation anticoagulant rodenticides (ARs), which affect numerous predators in both rural and urban settings. According to a 16-year study in southern California, urban bobcats have a high prevalence of notoedric mange as a result of high exposure to ARs (Serieys, Armenta, and Moriarty et al. 2015, 844). The researchers also found that "single-family high-density residential area[s] [were] among the most frequent land-use type to have positive associations with anticoagulant exposure" in the areas studied, even more so than areas zoned for agricultural use (855). These findings parallel those made by Short, who concluded that commercial landowners were far more knowledgeable about BMPs than residential landowners.

Case Study: Methods

This study consisted of a GIS-based spatial analysis following a visual search of the watershed using Google Earth imagery. Digital elevation models, Humboldt County administrative boundaries and assessor's parcels, and the Calwater 2.2.1 Watershed Boundaries were imported into ArcGIS, where the Redwood Creek watershed and parcels contained within or straddling the watershed were isolated. The resulting shapefiles were saved as KML files, which—along with the parcel and watershed boundaries and a UTM reference grid—were then imported into Google Earth. Sites identified were greenhouses, outdoor marijuana-cultivation gardens (commonly known as "grows"), water tanks, and installed ponds. Greenhouses were measured in Google Earth using the Ruler tool. Sites outside the boundaries of the Redwood Creek watershed, but on parcels that straddle the watershed, were recorded due to the possibility that they draw water from Redwood Creek and its tributaries.

After data were collected they were saved as KML files and imported into ArcGIS. Four point layers were generated from the KML files, one for each type of site. Each point layer was intersected with the newly created shapefile of Redwood Creek assessor's parcels, in order to determine the concentration of cultivation and water-storage sites per zoning classification (Table 1) and land-use designation (Figures 2, 3 and 4). According to the Humboldt County website, "Land use designations are more general than zoning classifications. Typically, land use designations focus on allowed uses, whereas zoning classifications provide specific standards related to building height and setbacks." Zoning classifications determine where, how, and how much marijuana can be cultivated. Land-use designations are useful to differentiate between parcels that have been developed for residential use and those that are used for purely commercial or recreational purposes.

Case Study: Results

There are 369 assessor's parcels within or straddling the Redwood Creek watershed, ranging in size from 0.02 ha (0.05 acres) to 306.34 ha (756.98 acres), with a total area of 8754.67 ha (21633.23 acres; Figure 2 and Table 1). Visual search and analysis of the watershed

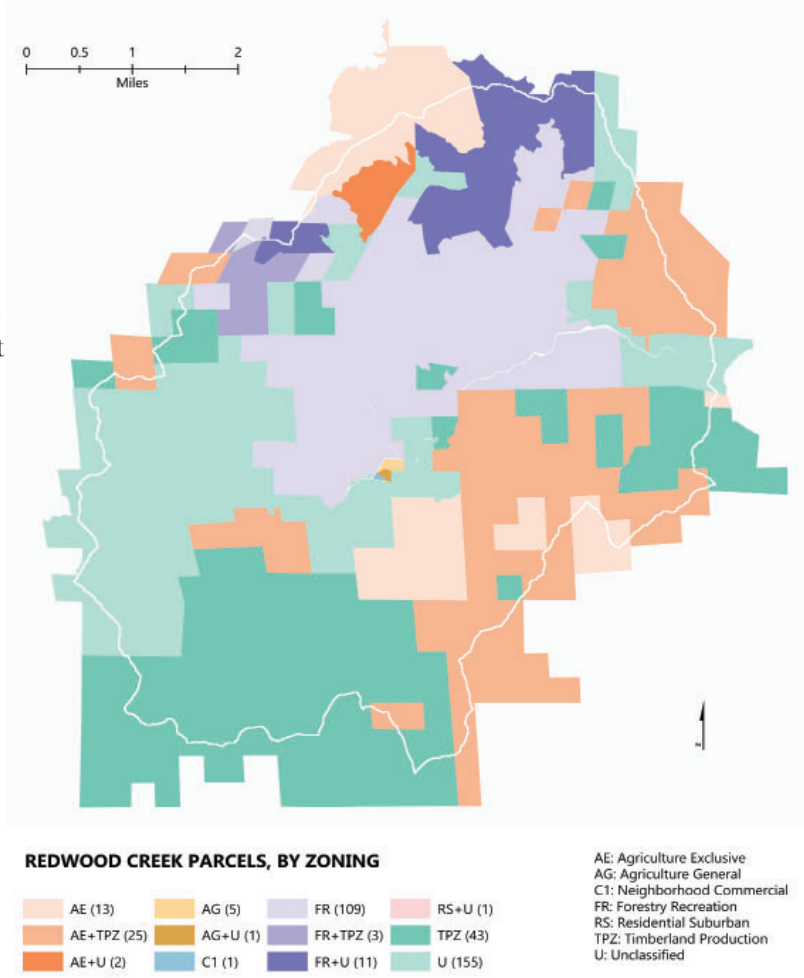

Figure 2. Parcels contained within or straddling the Redwood Creek watershed, by zoning classification (sources: County of Humboldt, Calfire; map by author).

TABLE 1. Number of marijuana-cultivation and water-storage sites, by zoning classification (source: County of Humboldt).

Zoning	Hectares	% of Total	# Parcels	Green-houses	% of Total	Outdoor	% of Total	Water Tanks	% of Total	Ponds	% of Total
AE	746.43	8.5%	13	16	5.3%	13	13.0%	12	7.3%	8	15.7%
AE+TPZ	1686.66	19.3%	25	8	2.6%	4	4.0%	5	3.0%	1	2.0%
AE+U	80.12	0.9%	2	6	2.0%	1	1.0%	0	0.0%	1	2.0%
AG	5.77	0.1%	5	0	0.0%	0	0.0%	0	0.0%	0	0.0%
AG+U	2.56	0.0%	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
C1	1.32	0.0%	1	1	0.3%	0	0.0%	6	3.7%	1	2.0%
FR	1585.22	18.1%	109	85	28.1%	37	37.0%	59	36.0%	25	49.0%
FR+TPZ	129.09	1.5%	3	1	0.3%	0	0.0%	0	0.0%	0	0.0%
FR+U	462.05	5.3%	11	25	8.3%	9	9.0%	2	1.2%	6	11.8%
RS+U	0.41	0.0%	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
TPZ	2248.45	25.7%	43	26	8.6%	10	10.0%	7	4.3%	4	7.8%
U	1806.59	20.6%	155	135	44.6%	26	26.0%	73	44.5%	5	9.8%
Totals	8754.67	100.0%	369	303	100.0%	100	100.0%	164	100.0%	51	100.0%

Key: AE=Agriculture Exclusive; AG=Agriculture General; C1=Neighborhood Commercial; FR=Forestry Recreation; RS=Residential Suburban; TPZ=Timberland Production; U=Unclassified.

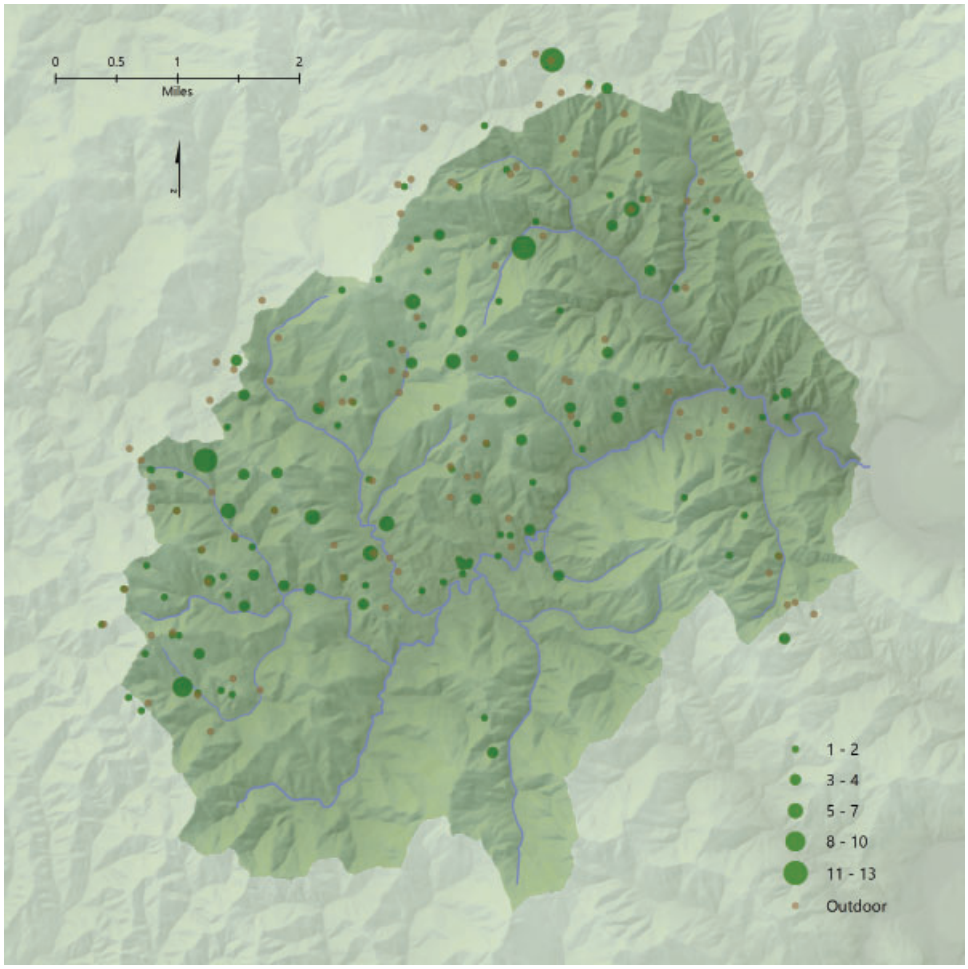

Figure 3. Simplified map of marijuana cultivation sites in the Redwood Creek watershed. Green circles represent clusters of greenhouses, by number; outdoor growing sites are mapped individually. Sites outside the boundaries of the watershed are on parcels that straddle two watersheds, and were recorded because they may draw water from Redwood Creek and/or its tributaries (sources: USGS Earth Explorer, County of Humboldt, Calfire; map by author).

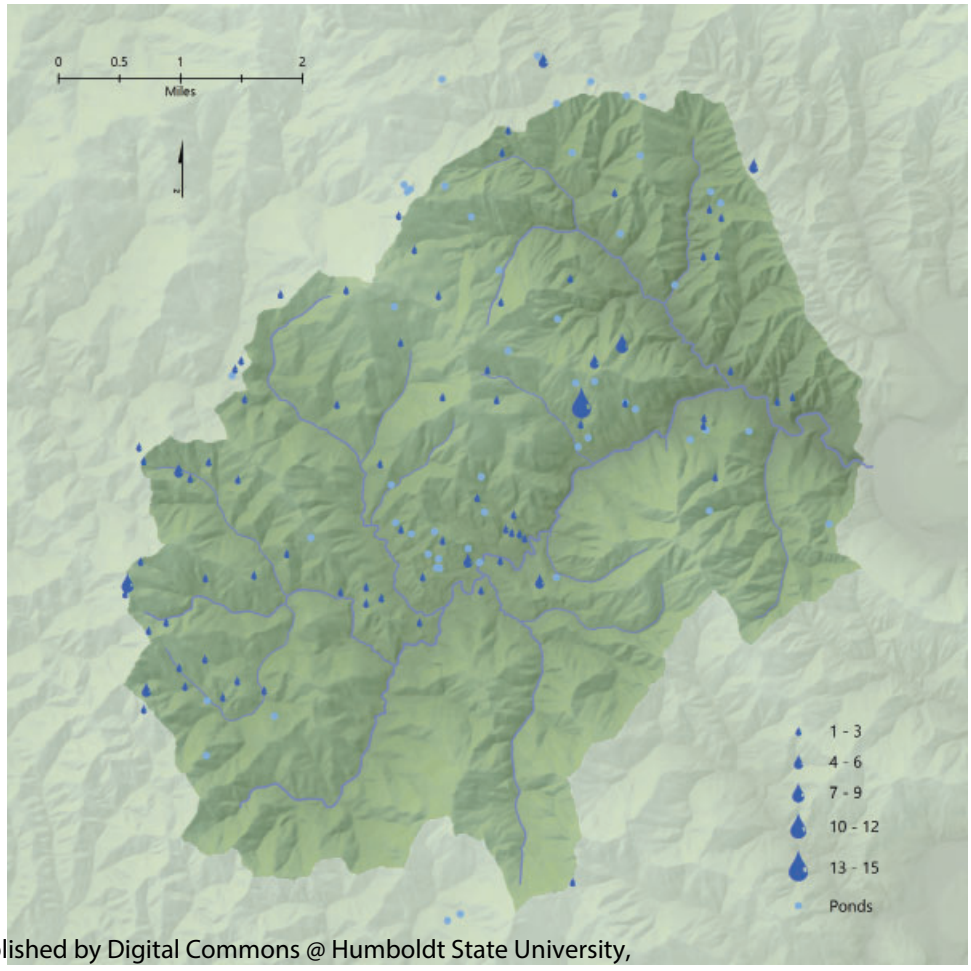

Figure 4. Simplified map of water-storage units in the Redwood Creek watershed. Water drops represent water tanks, by number; installed ponds are mapped individually. Sites outside the boundaries of the watershed are on parcels that straddle two watersheds, and were recorded because they may draw water from Redwood Creek and/or its tributaries (sources: USGS Earth Explorer, County of Humboldt, Calfire; map by author).

"It is imperative to quantify the extent of the industry and its environmental impacts to develop policies that prevent more damage.

yielded 303 greenhouses, 100 outdoor cultivation scenes, 164 water tanks, and 51 installed ponds. Outdoor cultivation scenes contained as few as 12 plants—so-called "mom-and-pop grows"—and as many as 170 plants.

Parcels zoned as "FR" account for only 18.1 percent of the land within or straddling the Redwood Creek watershed, but contain an estimated 28.1 percent of the greenhouses, 37 percent of the outdoor growing sites, 36 percent of the water tanks, and 49 percent of the installed ponds in the study area (Table 1). Similarly, parcels that remain "Unclassified" account for 20.6 percent of the acreage within or straddling the watershed, but contain an estimated 44.6 percent of the greenhouses, 26 percent of the outdoor growing sites, and 44.5 percent of the water tanks. However, they account for only 9.8 percent of the installed ponds.

Greenhouses were identified on only 122 parcels. Outdoor cultivation sites were identified on 73 parcels, water tanks on 77, and installed ponds on 38. Assessor's parcels with land use designations of "Rural Residential" or "Rural Residential, Vacant" account for 47.8 percent of the parcel acreage within or straddling the Redwood Creek watershed, but contain an estimated 86.1 percent of the greenhouses, 84 percent of the outdoor growing sites, 91.5 percent of the water tanks, and 82.7 percent of the installed ponds in the study area.

Discussion

Research and Analysis Challenges. These results likely represent a low estimate of the total number of water-storage and cultivation facilities in the Redwood Creek watershed. A number of the tanks found are partly visible under the forest canopy, and it is reasonably certain that some tanks are extant but cannot be located using satellite imagery. Additionally, tanks vary in size and water-storage capacity is difficult to estimate; two tanks with the same diameter may differ greatly in height. Pond depth, likewise, cannot be determined in a two-dimensional analysis.

Although it seems likely that the vast majority of greenhouses are used for marijuana cultivation, some are invariably used for other purposes. Conversely, it is also likely that many permanent structures—including former residential buildings—are used for marijuana cultivation.

Increase in Number of Sites Over Time. When comparing the Google Earth imagery from 2014 and 2012, there were numerous locations where new cultivation sites had been established, established cultivation sites had been expanded, and/or water tanks had been installed where none were extant before. These informal observations are consistent with the results of the study conducted by Bauer et al. (2015)—which used the 2012 imagery for analysis—and this study, which used the 2014 imagery. According to Bauer et al. (2015), in 2012 the estimated greenhouse capacity of the Redwood Creek watershed was 16,777 plants (2015, 12). Using the same calculations as Bauer, et al. (1.11484 m2 per plant), in 2014 the greenhouse capacity in the Redwood Creek watershed was 20,570 plants. If both studies are reasonably accurate, this represents an 18 percent increase in greenhouse capacity in just 21 months.

Conclusion

An accurate assessment of the extent of marijuana cultivation and water-storage capacity in the Redwood Creek watershed is not possible at this time, absent researchers' capacity to perform ground truthing. However, with both medical and recreational marijuana use now legal in California, it is imperative to quantify the current extent of the industry and its environmental impacts in order to develop public policies that prevent more damaging impacts from occurring and allow for remediation of existing environmental degradation. According to at least two peer-reviewed studies, residential landowners are not as knowledgeable of BMPs as commercial landowners. Given this fact, it is also imperative that rural-residential landowners—who comprise the vast majority of marijuana cultivators in the Redwood Creek watershed, and likely in other rural subdivisions in the Emerald Triangle—be educated about BMPs as the formerly underground marijuana economy transitions into a state-regulated industry.

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