Drone Forestry Career Pathways

Produced for the California Stewardship Network

Joshua Metz, Justin Cummings, Becca Fenwick and Michael Matkin

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Table of Contents

Gratitude

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About the Authors

Joshua Metz is an economic developer, land use planner and innovation ecosystem curator. Josh co-founded the Monterey Bay Drone, Automation and Robotics Technology Initiative to align industry, academia and governments towards these future growth sectors. Josh currently serves as a Senior Advisor with Regional Government Services Authority supporting local governments throughout the State of California in the areas of economic development, natural resource management and strategic planning. He previously served as the Executive Officer for the Fort Ord Reuse Authority, which coordinated the balanced reuse of the former Fort Ord Army Base on the Monterey Bay. Josh holds a Master of Landscape Architecture and Environmental Planning degree from UC Berkeley, and a Bachelor of Science degree in Environmental Biology from Humboldt State University.

Dr. Justin Cummings, is based at UC Santa Cruz and has been a drone operator and sensor technician since March of 2020. Justin Cummings, holds a BA in Spanish and a BS in Biology from Eastern Illinois University and a Ph.D. from the department of Ecology and Evolutionary Biology and a designated emphasis in Environmental Studies from the University of California, Santa Cruz. His work has focused on tropical forest restoration, plant physiology, invasive species ecology, ecosystem physiology, conservation science, environmental instrumentation, remote sensing using drones, and justice, equity, diversity, and inclusion program development and management. He also served as Mayor of the City of Santa Cruz in 2020 and has been on the Santa Cruz City Council since December of 2018

Dr. Becca Fenwick Is the co-founder of the UCSC CITRIS Initiative for Drone Education and Research and leads the statewide environmental and climate-monitoring California Heartbeat Initiative (CHI) for the UC Natural Reserve System (UC NRS). She is also the former Director of the Environmental Information and Technology Program for The UC NRS. Based at UCSC and in partnership with researchers at Berkeley and UC ANR IGIS, Becca has been spearheading the development of CHI, a long-term environmental monitoring program that uses UAV's, environmental sensors and satellite imagery to look at the health of the state's ecosystems. Becca earned her Ph.D in Marine Geology and Geophysics from Scripps Institution of Oceanography (UCSD). Previously, she served as the Director of two UC NRS reserves (Yosemite, Sequoia-Kings Canyon, and James San Jacinto Mountains).

Michael Matkin is the Assistant Director of CITRIS and the Banatao Institute, UC Santa Cruz. He works with the Director, J.J. Garcia-Luna-Aceves, managing and developing programs at the UC Santa Cruz main campus and Silicon Valley extension. Michael is a key team member responsible for launching the CITRIS Institute for Drone Education and Research (CIDER) and UC Santa Cruz. Prior to joining CITRIS he served as COO of an award-winning public relations agency in New York City that specialized in technology and healthcare clients.

Introduction

The fields of drones (Uncrewed Aerial Systems, UAS), automated systems, and robotics technologies (DART) have rapidly advanced over the past decade yielding new tools for environmental management and a broad array of other applications. These technological innovations are the result of both public and private research & development investment, and represent emerging markets for future workforce engagement. Over this same time period we have experienced increasingly frequent occurrences of climate driven catastrophes such as wildfire, drought and floods. As a result, there is real urgency to conceive of novel solutions to these environmental challenges. The hope is that drones and related technologies of remote sensing and spatial analysis can be part of those solutions, while providing value through generating future workforce opportunities.

Data collected by drones can be applied to a variety of environmental management fields including agriculture, environmental conservation, timber management, watershed management, climate change monitoring, disturbance mitigation, wildland management, fire management, and urban-wildland interface management among many others. Imagery data captured by drones for the purposes of land management and ecosystem monitoring can be used to evaluate ecosystem health under stress (Daly 2019), track and monitor wildlife (Prosekov et al 2020), pest outbreaks and disease spread (Filho et al 2020), ecosystem regeneration after disturbance, shifts in ecosystem after disturbance (Jiménez et al 2019), and monitor fires (Aydin et al 2019, Afghah et al 2019) among many other applications.

As drones become indispensable tools for land management, with the capabilities of drones to collect high frequency, high resolution data on a variety of spatial and temporal scales. We recognize that a critical priority for California is to have a workforce ready and able to support the innovation, manufacturing, and application of drones across a wide variety of industries.

With an eye towards informing workforce developers, educators and policy-makers focused on meeting the urgent need for a future focused forest management workforce, this paper provides:

- an overview of drone-related investment trends and technology education opportunities in California;
- an analysis of drone and forestry-related wage and hiring trends to paint a picture of recent market demand for drone and drone-related skills;
- Calls out the imperative to design and build a modern workforce that takes advantage of the inherent strength of our States rich cultural diversity; and
- contemplates a characterization of drone and forestry related career pathways.

Recognizing the inherent limitations of projecting emerging technology skill demands based on backward looking datasets, this paper also highlights innovative companies pushing the

envelope towards next generation drone-based forest land management applications. Finally, we characterize the current state of diversity, equity and inclusion in the STEM workforce, and present the case for explicit action to ensure the emerging drone and forestry related hiring makes room for a workforce reflective of the rich, cultural diversity of the State of California.

Emerging Markets & Training Opportunities

Over the past ten years we have seen a dramatic increase in the proliferation of drones for recreational and commercial uses. Since 2010, $6.9 billion dollars have been invested globally in the drone industry and in 2020, in spite of a global recession caused by the pandemic, the drone industry saw the highest year of investments at $2.3 billion dollars (Alvarado 2021). As uncrewed aerial systems (UAS) are incorporated into the US National Air Space (NAS), it is projected that the economic impact on the US will accumulate to more than $82.1 billion dollars between 2015 and 2025, and create more than 103,776 jobs by 2025 (Jenkins & Vasigh 2013). In particular, California is expected to lead the country in the most jobs created and revenue generated from the drone industry (Jenkins & Vasigh 2013). This increased investment in drones suggests that there will shortly be a corresponding increase in the market's demand for skilled labor that will design, manufacture, develop software, operate drones, and analyze the data. We are at a critical moment in this emerging field with the ability to address projected workforce needs and shape the diversity of this workforce.

Acknowledging the growing UAV field and the need for education and training around drones, in 2018 the Federal Aviation Administration's (FAA) Reauthorization Act required the FAA to establish a collegiate training initiative program related to unmanned aircraft systems (UAS). The FAA Unmanned Aircraft Systems Collegiate Training Initiative (UAS-CTI) was launched in April of 2020 and is designed for universities, colleges, and technical schools to be recognized as institutions that prepare students for careers in UAS or drones (FAA UAS-CTI). To date, there are 82 participating two- or four-year colleges/universities and technical schools participating as part of the FAA UAS-CTI. In California, of the 116 community colleges, 233 trade schools, and 281 four-year colleges and universities statewide (n= 630) only 10 schools are part of the FAA UAS-CTI, nine of which are community colleges and one 4-year college (Table 1). As the state with the highest population, over 2.71 million college students, and being one of the global tech giants, it is critical that California takes a lead role in developing a sustainable educational pathway toward creating a sustainable workforce for the emerging drone field.

Table 1. Current FAA UAS-CTI programs in California.

University Name	**City**	**Type of Institution**	**Degrees/Certificates Offered**
California Baptist University	Riverside	4-year college	B.S. Aviation Flight; Minor: Aviation UAS; Concentration: UAS
Fullerton College	Fullerton	Community College	Associate of Science in Autonomous Systems Development; Autonomous Systems

			Development Certificate; Unmanned Aerial System Piloting Certification
Merced College	Merced	Community College	Doesn't show certificates or degrees in the subject
MiraCosta College	Carlsbad	Community College	Unmanned Systems (ROV/Drone) Operator Technician Program with FAA Licensing Test Prep
Mt. San Antonio College	Walnut	Community College	Associates Degree in Unmanned Aircraft Systems
Palomar College	San Marcos	Community College	Drone Certification Program; Associates in Drones
Santa Rosa Junior College	Santa Rosa	Community College	Commercial Drone Certification Skills Certificate
Southwestern College	Chula Vista	Community College	Drone Technology and Applications Certificate Program
West Valley College	Saratoga	Community College	Drone Technology and Applications Certificate

There are many career pathways that are developing in drone industries, but most relevant to forestry applications are those that involve collecting and analyzing drone based aerial data. In order to operate a drone under the FAA's Small UAS Rule (Part 107), pilots must obtain a Remote Pilot Certificate from the FAA, demonstrating that the pilot understands the regulations, operating requirements and procedures for safely flying drones. The test for the 107 Certificate covers topics such as regulations, airspace, weather, loading and performance, operations, and night flying. Once you've passed the test, the license is good for 24 months and requires that operators take an online recurrent training course to remain current as a part 107 remote pilot. Prior to taking the 107 test, it is highly recommended to take an online prep course and practice exams to help prepare for the exam and there are a variety of online courses available to help prepare.

Although obtaining the flight 107 license is critical for being able to legally fly drones for commercial purposes, formal drone courses are also critical for learning practical flight skills, data management, safety, imagery processing and data analysis. Of the nine community colleges recognized by the FAA UAS-CTI program, three offer associates in drones or UAS, seven offer one or multiple certificates in drones and one offers classes only related to drone operation. The only four-year college recognized by the FAA UAS-CTI program offers a minor in aviation UAS or a concentration in UAS.

Given the lack of drone training opportunities there is a need and opportunity for universities, community colleges and trade schools, to create curriculum and pathways for careers in the drone field.

In addition to training for students to receive their FAA Flight 107 license, courses could range from introductory courses on drones and their application to flight training labs, photogrammetry, image processing, data analysis in GIS, sensor and drone engineering, videography, and more. It is clear that educational institutions would greatly benefit from creating courses and curriculum that could lead to meaningful careers in drones, which are going to be greatly needed in forestry and land management.

Employment Wages & Trends

We analyzed employment trends and typical wages for Standard Occupational Classification (SOC) codes using JobsEQ for two regions: the State of California and the North State Forestry Project Area (Figure 1). JobsEQ compiles national Bureau of Labor Statistics data on a quarterly basis.

Figure 1. North State Forestry Project Area.

For this analysis, we used 6-digit SOC codes in forestry, mapping and photogrammetry (Table 3), which are traditional forest management related roles that leverage data collection and analysis outputs generated from remotely sensed data platforms such as drones and aircraft. There are no existing job codes that specify drone expertise.

Table 3. Forestry, Mapping & Photogrammetry related SOC codes and mean 2020 wages in California and the North State Forestry Study Area.

SOC	Occupation	California	North State Forestry
45-4010	Forest and Conservation Workers	$14.75	$15.05
17-3020	Engineering Technologists and Technicians, Except Drafters	$34.41	$32.80
17-3030	Surveying and Mapping Technicians	$35.03	$32.44
17-3090	Calibration Technologists and Technicians and Engineering Technologists and Technicians, Except Drafters, All Other	$34.95	$35.26
17-1021	Cartographers and Photogrammetrists	$43.10	$41.75

Mean wages range between $14.75-$41.75/hr ($30,680 to $86,840/year) depending on job type and skill-level. These data support our anecdotal experience, interview results, and other UAV-focused wage assessments (Lee 2021) that point to increasing pay depending on technical skills, educational attainment and experience.

BLS SOC codes capture known job types and skills from prior reporting years. They do not represent well those job types and skills that are emerging or are growing in demand, thus are *not well suited to predict* emerging, new technology-based workforce demand. We believe the reported results miss the rapidly developing drone-based tools and skills that will be increasingly in demand as companies seek to leverage new technological capabilities.

For this study we used JobsEQ Real Time Intelligence (RTI) reporting to assess employment demand in relevant SOC codes from August 31, 2020 to August 31, 2021 (Table 4). The RTI data are a proxy for actual employment records, and are generated from online job postings in California and the North State Forestry project area. A total of 16,094 online job postings in the reported SOC codes were reported for the State of California and 1699 for the North State Forestry Project area during the analysis period.

Table 4. Forestry, Mapping & Photogrammetry related 6-digit SOC code Real-time Intelligence (RTI) Job Postings in California and the North State Forestry Study Area from 9/16/20 to 9/16/21.

SOC Codes	Occupation	California	North State Forestry
45-4010	Forest and Conservation Workers	1902	477
17-3020	Engineering Technologists and Technicians, Except Drafters	12067	1004
17-3030	Surveying and Mapping Technicians	573	88
17-3090	Calibration Technologists and Technicians and Engineering Technologists and Technicians, Except Drafters, All Other	1530	130
17-1021	Cartographers and Photogrammetrists	22	0
Totals		16094	1699

These results point to the strongest demand for engineering technologist roles, which correlates well with investment trends into new technologies and application development in the UAV sector. As these technologies and applications mature to the point of more widespread industry adoption, we would expect demand for hard skills in operations, image and other data analysis skills to grow. In addition, our analysis points to relatively weak demand in the Forest and Conservation Worker category. We would expect as the State and nation continue to grapple with the effects of climate driven landscape change - particularly the increasing frequency of catastrophic wildfire, that demand in this job category would also increase.

In addition to the SOC code-based search, we analyzed the RTI data using keywords to assess relevant demand across industries (Table 5). The results suggest a substantial job demand difference between the northern and southern portions of the State, as well as much larger current skills demand for spatial analysis expertise. Since Geographic Information Systems (GIS) are integral to turning remotely sensed data (i.e., imagery captured using sensors carried on drone platforms) into management relevant information, the demand for GIS skills suggests we should expect increased demand for drone piloting skills in the future.

Table 5. Keyword Search results of Real-time Intelligence (RTI) Job Postings in California and the North State Forestry Study Area from 9/16/20 to 9/16/21.

Keyword	**California**	**North State Forestry**
Drone Pilot	290	29
UAV	1045	93
Remote Sensing	824	145
GIS	9261	1643

Our analysis focused on a narrow set of forest land management related job types. A more expansive set of forest land management job types might include some of the following: wildfire risk reduction; forest product management; forest health; watershed management; urban-wildland interface; recreation management; climate change adaptation; spatial analysis and modeling; and conservation (among others).

Emerging Companies & Relevant Skill Sets

The results of our analysis suggest that while there are significant technological advancements and financial investments being made in drone and drone-adjacent markets, an uptick in hiring and hard skills focused job postings, especially in forest land management related fields, has yet to emerge.

In addition to the job types analyzed in this study, due to our team's work curating an innovation ecosystem on the leading edge of drone, automation and robotics technology development, we are aware of unique emerging technologies and applications that will likely deliver new tools and capabilities for forest land management applications in the near future. In this section, we highlight a few emerging and drone-forestry adjacent companies that are leading the way in developing these new capabilities, and point to future drone-forestry related workforce training opportunities and career pathways (Table 6).

Table 6. Emerging drone platform capabilities, missions, job types, and example companies in expanding drone-forestry market.

Capabilities	*Mission*	*Job Type*	*Example Company*
Sensor payload	Change detection; landscape characterization; health monitoring	Drone pilot; sensor technician; data analyst; field support	Treeswift; Planet; Micasense
Substance Dispersal	Reforestation; fire ignition; pest control	Drone pilot; support technician; forestry; hydrology; entomology	Drone Seed
Cargo transport	Wildfire support; search & rescue; restoration support	Drone pilot; Support technician; air traffic management;	Parallel Flight

Treeswift, based in Philadelphia, PA, is building the next generation of forest monitoring systems, providing forest stakeholders with precision data and analyses that are easily accessible and flexible. The platform leverages LiDAR sensors to deliver high resolution data and analytics for characterizing forest stand conditions. Treeswifts services are used in carbon capture estimation, timber value estimation, deforestation monitoring, advanced growth forecasting, and forest management.

Drone Seed, based in Seattle, WA, is focused on meeting the urgent need for rapid reforestation following increasingly frequent wildfires and large-scale timber harvesting across the globe. The team is working with a broad public and private stakeholder base including forest management agencies, nurseries, conservation groups and investors to rapidly scale a new drone empowered seeding capability.

Parallel Flight Technologies (PFT), based in La Selva Beach, CA, is developing a gas-electric hybrid drone platform that can carry heavy payloads (100+ pounds) and fly for up to 2-hours at a time. The PFT team is focused on delivering this platform as a new support vehicle to assist wildland firefighting efforts. Among other benefits, the platform would be capable of continuing to support remote firefighting teams even while visibility conditions limit piloted flight. While significant progress remains for safe and secure integration of such platforms into the firefighting toolkit, the team is making active progress and is working in collaboration with State and Federal agencies.

While these are just three companies in an active technology development and venture-investment arena, rapid scaling and deployment of such innovative forest-relevant businesses, will demand multi-disciplinary capabilities and/or teams. Specific skill sets that will likely be needed include: engineering, forestry/silviculture, ecosystem management, hydrology, data analysis, field operations, sales and marketing support among other job skills. It would be wise for regional education and training programs

to closely monitor the drone-forestry relevant innovation space in order to prepare a future-ready workforce.

Career Pathways

There are multiple potential DART-Forestry career pathways depending on one's starting point, educational attainment, work history, career interests and income needs. In general, the greater your educational attainment the higher your earning potential (Figure 2). Being that drone piloting and remote sensing image capture and analysis are tools within a larger forestry and ecosystem management career pathway, these skills generally add value and job seeking competitiveness.

Figure 2. SOC Code-informed Drone-Forestry Career Pathways

Improving Access, Diversity, Equity and Inclusion

Workforce diversity and overcoming discrimination remains at the forefront of the fight for justice in the workplace. Historically careers in science, technology, math, and engineering (STEM) lacked diversity. Women and Black, Indigenous, People of Color (BIPOC) have struggled to overcome workplace discrimination, assuming leadership roles, and overcoming racial and gender wage gaps. As the drone field emerges, it is critical that a culture around diversity, equity, and inclusion be instilled at the outset to overcome a historically racist, sexist, and discriminatory culture in STEM.

Although there are numerous laws that explicitly prohibit discrimination on the basis of age, race, color, religion, sex, or national origin (US Equal Opportunity Commission) diversity often is not proportionately reflective of the national demographic in STEM fields (Taylor 2014, Pearson and Schuldt 2014, AAUW 2021). Results from the 2020 census shows that in the US, although the white non-Hispanic population remains the most prevalent racial or ethnic group at 57.8%, this is down from 63.7% in 2010, which is

the lowest on record (Jensen et al. 2021; Figure 3). The Hispanic or Latino population is the second largest at 18.7% and non-Hispanic African Americans at 12.1% in third. In total, BIPOC comprise 42.2% of the population and although population growth slowed between 2010 and 2020, the increased growth was amongst people who identified as Hispanic, Asian, Black and more than one race. Although we are seeing increases in the number of BIPOC in the US as a whole, BIPOC experience higher rates of poverty at 41.8%, with the poverty rate for blacks at 18.8%, followed by Hispanic/Latino at 15.7% and Asian at 7.3% (Creamer 2020).

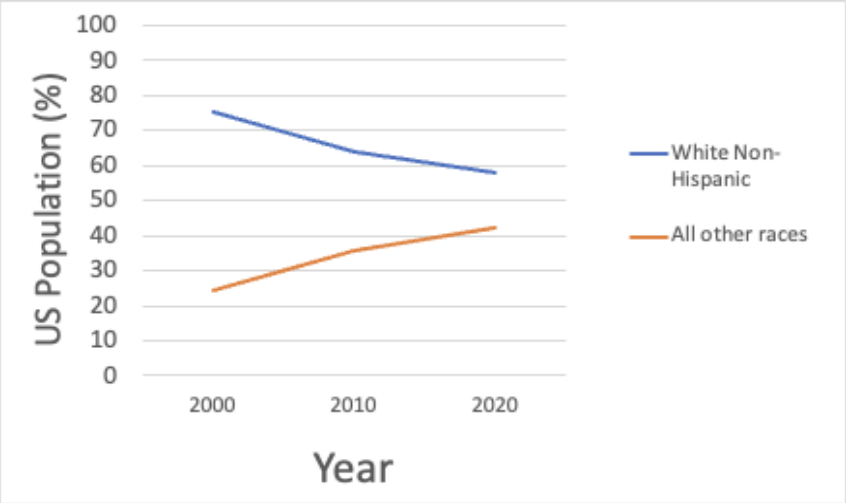

Figure 3. US Census data showing the change in white non-Hispanic and all other race populations from 2010 to 2020. As non-white Hispanic populations are decreasing, we're seeing an overall increase in all other races.

Based on the US population distribution across race and gender, one would expect representation in STEM fields to reflect the national demographics. However, STEM careers suffer from a culture that has not put an emphasis on equity and inclusion, and as a result these fields continue to lack diversity, despite the laws in place and acknowledgement of the lack of diversity. Although people of color made up 38% of the US population between 2010 and 2020, they only made up ~ 29% of the science and engineering workforce (Taylor 2014) and ~12% of jobs in the fields of conservation and forestry (Pearson and Schuldt 2014; Figure 4). We also see a decrease in racial and gender diversity as you move up into positions of leadership in these fields.

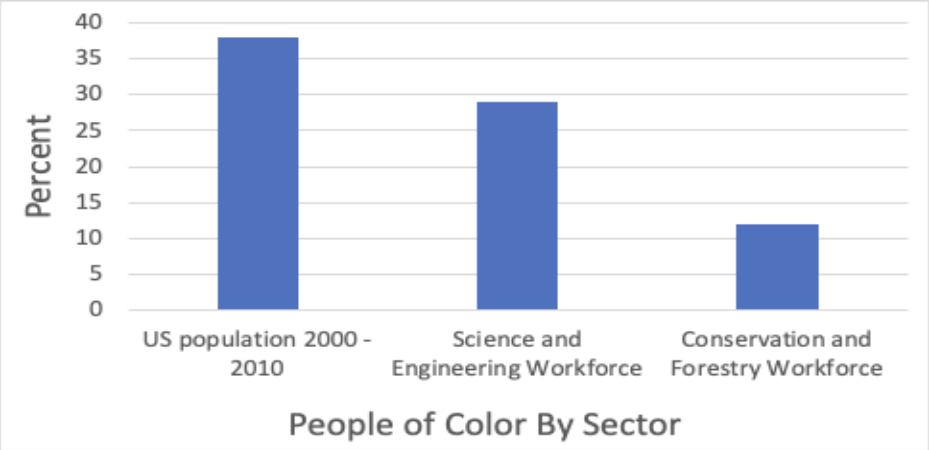

Figure 4. Population demographics for the percentage of people of color in the overall US population compared to the demographics of people of color in the science and engineering workforce, and in the conservation and forestry workforce.

The Green 2.0 study released in 2014 surveyed 191 conservation and preservation organizations, 74 government environmental agencies, 28 environmental grantmaking foundations, and reported the findings of interviews conducted with 21 environmental professionals who were asked to reflect on the state of diversity in environmental institutions (Taylor et al. 2014). This study revealed that while the representation of women had increased in these fields, women were most often white and were still largely excluded from positions of leadership (Taylor et al. 2014). These results suggest that efforts to increase representation have worked to increase the number of white women in conservation and environmental fields, and these same efforts need to be implemented to increase the number of people of color in these fields and there needs to be an emphasis on increasing representation at the highest levels of leadership down to entry level interns for both women and people of color.

California is known for being a tech powerhouse in the United States and is home to some of the world's largest tech companies, many of which offer high paying entry level jobs with good benefits and stock options. However, the tech field continues to be dominated by white men. In 2014, Google disclosed information on its US workforce demographics, which revealed that Google was performing poorly at hiring and retaining women and people who identified as Hispanic or black (Jacobson 2014). In the US, 61% of Google's workforce is white, 30% is Asian, 3% are Hispanic/Latinx, 2% are black, and 4% identify as two or more races (Jacobson 2014). This is not strikingly different from other companies in the Tech field. In a 2017 report that compared Uber's diversity numbers to those of Facebook, Apple, Google, Twitter and Microsoft, we saw similar trends where, after removing Asians from the category of BIPOC, people of color made up $\leq$ 23% of the total employees in these companies, held $\leq$10% of the leadership positions, and held $\leq$18% of the tech roles in these companies (Carson and Gould 2017).

We saw similar gender disparities with respect to STEM positions held by women and gender wage disparities. Although women make up $\geq$ 51% of the US Population, women make up only 28% of the overall workforce in STEM (AAUW 2021; Figure 5) held $\leq$ 30% of the positions of leadership, and were in $\leq$ 23% of the tech positions across the same companies (Carson and Gould 2017).

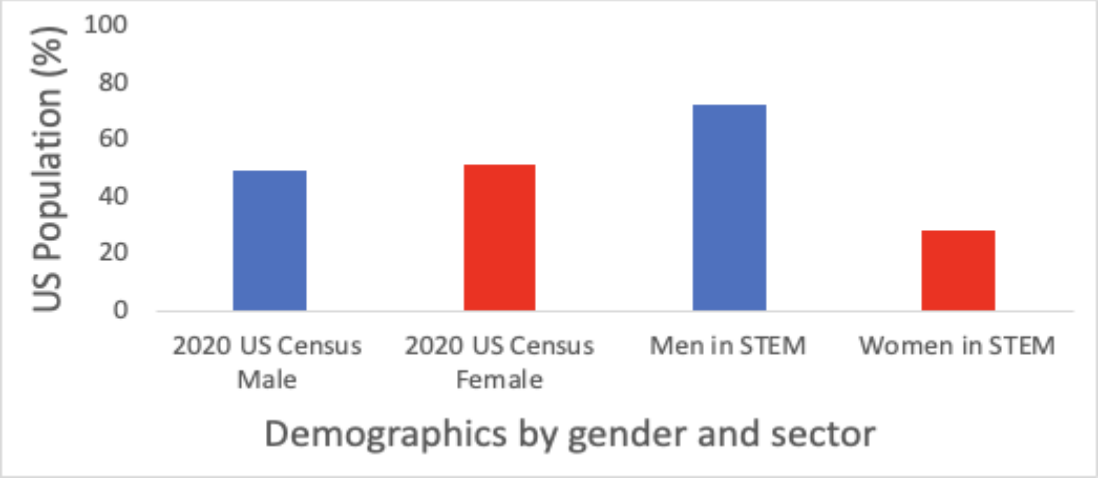

Figure 5. Percentage of the US population that identify as male and female compared to the percentage of men and women in STEM careers. Although the percentage of people who identify as female in the US is slightly higher than those who identify as male, more than double the number of positions in STEM are held by men when compared to women.

In addition to women holding disproportionately fewer positions in STEM careers, women on average also make $15,000 less per year than men ($80,000/year for men; $60,828/year for women), and $33,000 less for women who identify as black or Latina ($52,000/year; Figure 6; AAUW 2021).

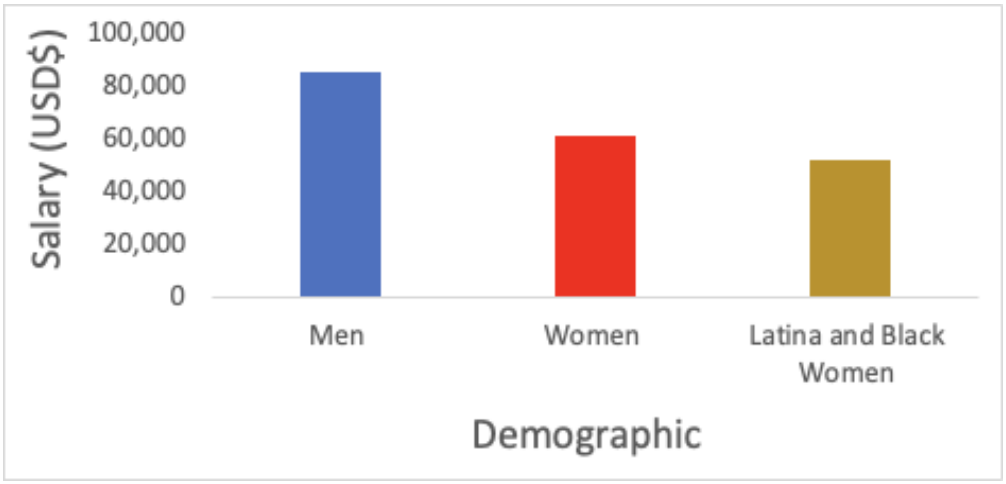

Figure 6. Average STEM salaries for men, women, and black and Latina women. Women on average make $15,000 less than men and Latin and black women make $33,000 less than men on average.

It is clear that based on the demographics of the US and representation in the STEM workforce, intentional efforts need to be made to evaluate the factors that prevent women, Hispanics, and African Americans from entering these fields and from holding positions of leadership, eliminate gender and racial wage disparities, and remove barriers to entry in existing and emerging STEM fields. Today, many environmental government and non-government organizations, foundations, and organizations, along

with many tech companies, are taking concrete steps to address diversity and promote inclusion and equity at all levels. Companies like Uber have created diversity resource pages for employees and are now publishing their diversity data online. The Green 2.0 initiative continues to track and publish transparency report cards to illuminate diversity gaps in environmental and conservation related foundations, non-government organizations, and government institutions to create a path towards increasing diversity in conservation and environmental fields.

As the drone industry emerges and the application of drones becomes more widely utilized, it is critical that we introduce these career opportunities to people who have been historically excluded from STEM fields. To that end, the US Department of Education, Hispanic Serving Institution (HSI) Designation provides unique grant funding for eligible institutions that enroll at least 25% Hispanic students. This designation is particularly relevant to universities and community colleges in California that host such a large Hispanic population. Numerous campuses on the Central Coast of California meet this criterion including UC Santa Cruz, CSU Monterey Bay, Hartnell College and many others. These campuses are able to leverage access to Federal funds to improve STEM opportunities for their diverse student populations.

For example, at UC Santa Cruz, the UCSC CITRIS Initiative for Drone Education and Research (CIDER) is working to create a drone education and research program aimed at educating students on the design, development, and application of drones, with an emphasis on targeting students traditionally underrepresented in STEM, to help create pathways for entry into the drone industry and application of drones. In addition, The GANAS Career Internship Program is part of a new initiative at UC Santa Cruz that places underrepresented, low-income, and/or Latinx/e/a/o students in paid internships situated in one of the six high-demand fields of Accounting/Finance, Bio-tech, STEM, Health, Agriculture, and Teaching/Education.

Similarly, this year the UC Drone Camp offered scholarships to undergraduate and graduate students, and emphasized supporting people who were traditionally underrepresented in STEM. Of the 53 scholarship applicants and recipients, 56.6% were men, 39.6% were women, and 3.8% were gender non-conforming/non-binary. When we looked at applicants by race, 55.8% of scholarship applicants and recipients were people of color. This suggests that not only are women and people of color interested in drone technology and the drone field, but it is important that we provide mentoring and support opportunities for underrepresented people to stay in this field.

Conclusions

Drones, automation and robotics technologies (DART) have seen significant public and private research and development investment and the emergence of cutting-edge capabilities over the past ten years. These advances have led to the creation of previously unavailable tools and applications for environmental management and a broad array of other sectors. During this same period, we have experienced increasingly frequent climate driven catastrophes such as wildfires, droughts and floods. The hope is that these new technological capabilities in drones and drone-related technologies like remote sensing and spatial analysis, can yield new insights and management guidance to help address these challenges.

In California, the increasing frequency of catastrophic wildfire is driving strategic efforts across the State to find solutions. This paper delivered insights about the drone market and relevant educational opportunities at community colleges and universities. We provided a current analysis of wage and hiring trends across a range of forestry and drone technology related SOC codes. While indicating strong engineering skills demand, our analysis did not find significant historic employment demand in low to mid-skilled forestry and conservation focused positions. We pointed out the challenge of characterizing emerging job types and skills by analyzing historical data, and provided descriptions of cutting-edge companies leading the way towards broader and more impactful use of these new technologies in forestry-focused applications.

Our hope is that this paper provides some guidance and inspiration for workforce developers, educators and policy makers in growing the future forestry workforce. To that end, we characterized a drone forestry career pathway that makes room for multiple on and off-ramps, and a range of educational attainment levels with the aim of illuminating potential career pathways for young people looking to combine interests in technology and addressing urgent climate drive challenges, while recognizing the modern reality of diverse timeframes and pathways. Recognizing the critical need to build a workforce that represents and takes advantage of the rich cultural diversity of our State, we also highlighted the historic dearth of diversity representation in STEM fields. Since the drone and drone-related workforce demand is emerging, we made the case for proactive engagement of women and people of color in growing the drone forestry workforce.

References

Afghah F., A. Razi, J. Chakareski and J. Ashdown, *Wildfire Monitoring in Remote Areas using Autonomous Unmanned Aerial Vehicles*, IEEE INFOCOM 2019 - IEEE Conference on Computer Communications Workshops, 2019, pp. 835-840

Alvarado, E. *Global Companies Invest in Drones Despite Recession*. Drone Industry Insights. May 2021. https://droneii.com/global-companies-invest-in-drones-despite-recession

American Association of University Women. 2021. *The STEM Gap: Women and Girls in Science Technology Engineering and Math.* https://www.aauw.org/resources/research/the-stem-gap/

Aydin, B., E. Selvi, J. Tao, and M.J. Starek. *Use of Fire-Extinguishing Balls for a Conceptual System of Drone-Assisted Wildfire Fighting*. Drones 2019, 3, 17. https://doi.org/10.3390/drones3010017

Carson, B. and S. Gould. 2017. *Uber's Diversity Numbers Aren't Great, But They're Not The Worst Either - Here's How They Stack Up To Other Tech Giants.* Business Insider. https://www.businessinsider.com/uber-diversity-report-comparison-google-apple-facebook-microsoft-twitter-2017-3

Creamer, J. 2020. *Inequalities Persist Despite Decline in Poverty For All Major Race and Hispanic Origin Groups.* Unite States Census Bureau. https://www.census.gov/library/stories/2020/09/poverty-rates-for-blacks-and-hispanics-reached-historic-lows-in-2019.html

Daly, K. and P. Paul. *The use of drones in environmental compliance*. Natural Resources & Environment, Chicago, Vol. 33, Iss. 4, 2019, Pages 59-63.

Drone Seed https://droneseed.com/

Federal Aviation Administration (FAA). *UAS Collegiate Training Initiative*. United State Department of Transportation. Last updated: June 5, 2021. https://www.faa.gov/uas/educational_users/collegiate_training_initiative/

Filho F., W.B. Heldens, Z. Kong, and E.S. de Lange. *Drones: Innovative Technology for Use in Precision Pest Management*. Journal of Economic Entomology, Vol. 113, Iss. 1, 2020, Pages 1–25. https://doi.org/10.1093/jee/toz268

Jacobson, M. 2014. *Google Finally Discloses Its Diversity Recorrd, and It's Not Good.* PBS News Hour. https://www.pbs.org/newshour/nation/google-discloses-workforce-diversity-data-good

Jenkins, D., and B. Vasigh. *The Economic Impact of Unmanned Aircraft Systems Integration in the United States*. Association for Unmanned Vehicle Systems International (AUVSI), 2013.

Jensen, E., N. Jones, M. Rabe, B. Pratt, L. Medina, K. Orozco, and L. Spell., *2020 U.S. Population More Racially and Ethnically Diverse Than Measured in 2010.* US Census Bureau. https://www.census.gov/library/stories/2021/08/2020-united-states-population-more-racially-ethnically-diverse-than-2010.html

Jiménez López, J., and M. Mulero-Pázmány. *Drones for Conservation in Protected Areas: Present and Future*. Drones 2019, 3, 10. https://doi.org/10.3390/drones3010010

Lee, I. Drone Pilot Salary — How Much Money do Drone Pilots Make? UAV Coach. 2021. https://uavcoach.com/drone-pilot-salary/

Parallel Flight Technologies https://www.parallelflight.com/

Prosekov A, A. Kuznetsov, A. Rada, and S. Ivanova. *Methods for Monitoring Large Terrestrial Animals in the Wild*. Forests. 2020; 11(8):808. https://doi.org/10.3390/f11080808

Treeswift https://www.treeswift.com/

US Equal Opportunity Commission. *Federal Laws Prohibiting Job Discrimination: Questions and Answers. https://www.eeoc.gov/fact-sheet/federal-laws-prohibiting-job-discrimination-questions-and-answers*