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Using Geospatial Analysis for High School Environmental Science Education: A Case Study of the Jane Goodall Institute's Community-Centered Conservation Approach

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Abstract

Given my experiences as a young conservation advocate, I saw a need to teach students the importance of interconnectedness, cultural awareness and systems-thinking skills through a spatial lens. I believe these skills are required for holistic, equitable and sustainable conservation decision-making in local and international contexts. This thesis uses geospatial tools to teach conservation ecology vocabulary and concepts from high school environmental science curriculum in two online resources. The purpose of my lesson plan is to show students how conservationists address complex conservation and land-use challenges using the Jane Goodall Institute's community-centered conservation approach as a case-study. My hope is that these lessons empower students to become change-agents in their communities.

Chapter 1: Background

My dedication to conservation began as a 7th grader when I learned that Girl Scout USA used palm oil in its cookies. After sending an email to the Manager of Product Sales outlining its moral obligation to stop using palm oil, I assumed the organization would change its ways immediately. This wasn't the case and I spent my adolescent years growing Project ORANGS, a campaign for sustainable palm oil in Girl Scout cookies, from a middle school initiative to an international platform. This required crafting a communications strategy, reaching scale by engaging consumers, earning legitimacy through expert partnerships, and garnering cross-cultural, cross-sector buy-in. This thesis is a culmination of the last decade of my life's work. As an environmental educator, my mission is to foster interconnected systems thinking and cultural awareness through a spatial approach. I believe that these skills are required for holistic, equitable and sustainable conservation decision-making. Here's why:

Interconnectedness

Inspired by a first grade field trip to watch "Jane Goodall's Wild Chimpanzees," I decided that I wanted to save animals like Dr. Jane. After learning that endangered orangutans' rainforest habitat in Indonesia and Malaysia is cleared for palm oil plantations, and that palm oil is in 50% of products in American grocery stores, my 6th grade mission was to save this species from extinction (Rainforest Action Network n.p.). At this time, I joined Jane Goodall's Roots & Shoots program, and its philosophy taught me that the health of people, animals, and the environment are interconnected. Unsustainable palm oil production was not only driving orangutans to extinction, it had other grave environmental and social costs. I learned that Indonesia and Malaysia's rainforests are home to other endangered species like proboscis monkeys, clouded leopards and Sumatran tigers and that a palm oil plantation could only provide adequate habitat for around 15% of animal species found in a primary rainforest (Fitzherbert et al. 540). Deforesting land and burning peatland also releases massive carbon dioxide emissions, making Indonesia the third largest emitter of greenhouse gases in the world behind the United States and China. The conversion of these forests for plantations had illegally stripped thousands of indigenous people of their culture, food sources and livelihoods despite the United Nations' "Declaration on the Rights of Indigenous Peoples" which declares that these communities have "community tenure" rights to the land that they have traditionally owned, occupied or used. Even after the plantations are established, social exploitation can continue, with the U.S. Department of Labor linking oil palm production to child labor in Indonesia and forced labor in Malaysia.

Systems Thinking

The first step in my advocacy was researching the issue from multiple perspectives. Upon discovering that palm oil was in the Girl Scout Cookies I had sold since first grade, my initial plan was to stage a boycott. At 11 years old, I assumed that boycotting would fix the problem because if I could stop palm oil production, then rainforests would not be destroyed. When I presented my petition to Dr. Jane Goodall, she crossed out my call to action, "I won't buy Girl Scout cookies unless the palm oil is removed", and rewrote, "until the palm oil is sourced from a sustainable plantation." My stubborn 11-year-old mind felt this compromise was unacceptable, and I did not understand why this renowned conservationist declined to endorse my project. But, I grew to realize that Dr. Goodall was right. I was not anti-palm oil, but rather against clear cutting rainforest for oil palm plantations. The next step of my research was to discover why palm oil was used in the first place. I learned that palm oil is attractive to farmers because the fruit bunches can be harvested year-round. Compared to other vegetable alternatives like soy, canola, olive and corn oil, it is 5-10xs more productive (May-Tobin et al. 12). If my ultimate goal was to reduce the area of land under cultivation, then palm oil in fact was a reasonable option. Palm oil also appeals to bakers because it is solid at room temperature, trans-fat free and has a long shelf life. These versatile properties make it a viable substitute for expensive and perishable animal products like butter.

Adopting a systemic, interconnected approach to understanding palm oil's popularity and the impacts of its production on people, animals and the environment made me realize that boycotting palm oil would not fix the industry. I could not blame Girl Scouts USA or any single company for the abuses caused from its production. Even if I removed palm oil from Girl Scout cookies and all American products, the largest consumers of palm oil are China and India. To have industry-scale impacts, I had to engage the palm oil suppliers and traders. Finding expert partners from nonprofit organizations with a variety of missions strengthened my campaign's validity. Partnering with groups like the Rainforest Action Network, Climate Advisors, Orangutan Outreach, Cultural Survival, Witness for Peace and the Union of Concerned Scientists introduced me to a new perspectives. Incorporating social and environmental concerns into my campaign allowed me to appeal more than just animal lovers like me. For more than five years, I worked with these nonprofit partners to develop social media campaigns and online petitions that introduced hundreds of thousands of consumers to the problem with unsustainable palm oil.

Cultural Awareness

When I was 14 years old, media outlets picked up my story, sparking international acclaim and critique. The United Nations Forum on Forests awarded me with their highest honor for showing millions of Americans how daily purchases impacted wildlife and forests abroad. My acceptance speech chided Malaysia and Indonesia for their high deforestation rates. Expecting congratulations, I was startled when the director of the UN Forum on Forests remarked:, “Madi, you can’t put a fence around a forest.” My idealism made headlines, but I had to face reality: forests are natural resources that have been and will continue to be exploited for human use. The Malaysian Plantation Minister responded to my inflammatory remarks on NPR by pushing back, saying:, "I think it's time, perhaps, that these little girls get better informed." I realized that diplomacy required understanding the viewpoints of people from the countries that I was calling out and of palm oil industry stakeholders. If I was going to continue speaking in international forums, I had to acknowledge my privilege as a white American, the historical appropriation of oil palm through the establishment of industrial plantations and the brutal colonization of palm oil producing countries.

Building a consensus was the tipping point for my campaign and it began by meeting with palm oil supply chain representatives and acknowledging the validity of their positions. No individual producer would change methods if it would increase overhead costs and put them at a competitive disadvantage. No single consumer brand would change its sourcing policy if there were no clearly defined sustainability guidelines to adopt. Because my nonprofit partners were prohibited from the negotiations, my co-founder and I presented the sustainable palm oil criteria that became the basis for later adopted policies. In 2011, the Girl Scouts announced they would offset their palm oil consumption and print a GreenPalm sustainability logo on every cookie box. Three years later as a result of our efforts and those of our nonprofit partners, Kellogg, (cookie baker) Cargill, (largest US supplier), and Wilmar (trader of 45% of the world's palm oil), adopted groundbreaking deforestation-free commitments. By 2015, 90% of palm oil traded internationally was bound by deforestation-free policies (Butler n.p).

After these landmark decisions, I thought that my job as an advocate was done. My politics, economics and history courses in college made me realize that a policy on paper is insufficient without ground-level implementation. While the deforestation-free policies defined the criteria for sustainable palm oil, its implementation relies on local stakeholder and government investment because they are ultimately the enforcers. Through interactions with communities in Colombia, Singapore, Malaysia, Cambodia, and Japan and by studying the Jane Goodall Institute's community-centered conservation strategy, I realized that foreign conservation actors must earn local communities' investment and trust by incorporating their feedback and interests into sustainability policies and conservation plans.

Multidisciplinary Spatial Thinking

To listen to local perspectives of Indigenous communities concerning forest conversion for palm oil production and a proposed hydroelectric dam project, I traveled to Malaysia with EnviroLab Asia, a Claremont Colleges initiative to connect the Asian Studies and Environmental Analysis departments. The Indigenous Dayak tribes were resisting logging and the dam by blockading roads to prevent trucks from pillaging the cloud forests they stewarded for generations. The Malaysian government had denied these communities their land rights, designated parts of their land for palm oil concession and was planning to build a hydroelectric dam that would displace 20,000 people. One evening is ingrained in my memory: sitting outside a longhouse along the Baram River, a Dayak elder played his Sape, a string instrument made of wood only found in these forests. Community members began dancing to the music, celebrating their reliance on and relationship with their environment. This experience further reinforced to me that there are numerous ways knowing and celebrating one's home, environment and heritage.

Performance is one form of understanding place, and applying multiple disciplines can lead to a more nuanced and complicated understanding of a region's development. For example, from a religious perspective, the Dayak group's pagan and Christian beliefs influenced their spiritual relationship to their environment. They vehemently opposed the dam because it would flood their churches and burial sites. From an ecological approach, evaluating the river's water quality through pH, dissolved oxygen levels and turbidity measurements allowed us to analyze relationships between deforestation for agriculture, erosion and river health. Through an economic lens it was possible to compare the benefits and costs of the dam project and palm oil cultivation.

Visualizing how cultural and scientific perspectives relate is possible through spatial thinking. In partnership with the Dayak tribes, nonprofit groups like SAVE Rivers, the Borneo Project and Bruno Manser Funds were building community maps to depict culturally significant locations like hunting grounds and burial sites and overlaying ecological data like forest cover, oil palm plantation boundaries and a buffer layer showing the area of land that would be flooded if the dam was built. These maps were used in lands rights cases as evidence of long-held occupancy by the indigenous groups and to model the impacts of the proposed dam project. Intrigued by this approach, I began investigating how the Jane Goodall Institute employs community mapping to facilitate knowledge exchange with communities outside of Gombe National Park. Coupled with demographic and ecological data these maps reveal the causes of environmental degradation and evaluate the potential effectiveness of conservation plans.

Throughout my conservation advocacy, I came to understand the importance of multidisciplinary systems thinking, cultural awareness, and the interconnectedness of people, animals and the environment. In this thesis, I argue that these skills can be taught effectively through a spatial perspective. Visually representing the ecological threats a species faces like habitat fragmentation and forest cover loss, with a place's socioeconomics and culture can reveal connections between biodiversity, people and their shared ecosystem. To determine the potential of GIS to expand environmental education's impact, I review the literature examining place-based pedagogy and critical global thinking and then develop a GIS lesson plan. The plan's objective is to help students assess how the Jane Goodall Institute (JGI) uses community mapping and land use planning to evaluate the political, historical, religious, economic, and ecological realities confronting the villages outside of Gombe National Park in Tanzania. JGI's work, conducted in partnership with these communities, is to develop equitable, holistic and sustainable conservation decisions. As students come to understand this process, they can then begin to recognize whether and how these tools can improve their own communities. In exploring the realities of a place and community that they are not members of, students will be challenged to examine the interconnectedness between people and animals in their lives and to recognize the importance of cultural and environmental consciousness in an international conservation context.

Chapter 2: Literature Review

Environmental Education: Local to Global

Meaningful environmental education for the 21st century should facilitate student discovery of the interconnectedness of individual localized experiences to international natural and human systems. The scholarly literature shows that teaching students systems-based thinking and spatial visualization to explore the connections between the political economy and environment through macro and micro scales encourages holistic problem-solving. The following review is an introduction to the prevailing geography teaching pedagogies in environmental education and a critique of those methods. It is important to acknowledge the concerns surrounding teaching global thinking so that environmental educators can improve global environmental education materials and in doing so help prepare the next generation of culturally competent, environmentally aware and actively engaged citizens.

Environmental education has the potential to inspire lifetime environmental stewardship by using a spatial perspective to link classroom material to daily lived experiences and identity. Gruenewald explains that Homo sapiens and other species live embodied and emplaced lives, clarifying Clifford Geertz's 1996 proclamation that "no one lives in the world in general" (qtd. in Greenwood 93). Incorporating the concept of place into curricula allows children's observations to serve as the foundation for their learning. This makes it easier for students to understand why they are learning the material in the first place (Smith 213). One of the founders of place-based education, Aldo Leopold wrote in his 1949 *A Sand County Almanac*: "our educational and economic system is headed away from, rather than toward, an intense consciousness of the land" (qtd. in Greenwood 93). Affective consciousness can be cultivated through a landscape approach that analyzes spatial patterns through time to observe the impact of human practices on the environment. This pedagogy emphasizes the observer's evolving position and perspective as they come to recognize their place in their community and the world at large (Brandt 277).

The purpose of critical place-conscious education is to use history, socioecology and ethics to discover/recover/reconstruct one's sense of self in relation to place (Greenwood 99). Affinity for local landscapes and identify formation can develop in the classroom and/or through imaginative outdoor play. Conducting a survey in northeast England to assess children's attachment to their neighborhoods, Roe (2007) discovered that children show a strong affinity towards their neighborhood landscape in particular towards self-identified "special places." Roe argues that children can provide a valuable perspective to city planners in the decision-making process regarding the management of these spaces (qtd. in Brandt 278). I argue that environmental educators should foster civic responsibility and agency by encouraging local youth to share their perspectives with city planners and conservationists because they are already actors in these landscapes and will soon inherit them.

Place-based pedagogy is a framework to help students develop a multifaceted, holistic understanding of their community and world by examining how the environment and humans interact with and influence each other. Greenwood points out that the education literature often explores culture and environment as separate topics, but place-based analyses reveal how "all cultures are nested in biophysical environments, and that environments are culturally produced or experienced" (94). There is an exchange in which places influence human experience and people shape places. Greenwood argues that critical place-consciousness means showing students how places are not inevitable or predetermined, but rather a cultural product of intended and unintended consequences. Gruenewald underscores this perspective, arguing that critical place-based pedagogy should help students investigate social inequity and power systems like colonization, coupled with opportunities to improve or reinhabit their own places. Buxton's 2010 study successfully led middle school students through this approach in a week-long local investigation of water issues with the objective of using environmental science for social justice. Through this analysis, students from diverse socioeconomic backgrounds developed a complex understanding of how safe water access is tied to social position; this motivated them to learn more because they were able to answer "Why here?" and "So what?" (qtd. in Smith 219).

A place-based approach begins with a local focus relevant to students' lives and then relates it to others' experiences and other places at regional and global scales. It is important that students not only recognize that places are cultural products, but that places are perceived differently by different cultural groups who hold unique ways of being and knowing. Understanding a place then, requires learning the diverse and competing stories told about it (Greenwood 98). A critical investigation acknowledges the dominant story in addition to the perspectives at risk of being silenced or erased, including the voice of the land itself (Greenwood 98). Greenwood notes that the study of place adds meaning to contemporary globalization discourse, which can imply a kind of "placelessness" or a "geography of nowhere" (98). It is imperative that students learn to embrace our shared global and multicultural reality but critics claim that place studies reinforce a limited interpretation of international topics. In response, Greenwood argues that thinking globally begins by acknowledging the planet as a mosaic of diverse experiences within places (94).

For almost 50 years, global thinking has been widely incorporated into environmental education curricula with some problematic consequences. In 1972, molecular biologist René Dubos urged the audience at UN Conference on the Human Environment to "think global, act local," a viral phrase today printed in textbooks and on T-shirts alike (qtd. in Gough 33). In 1974, UNESCO-UNEP's International Environmental Education Programme piloted this concept by encouraging school children everywhere to link their local and regional environmental action projects to global environmental health. Gough observed that the materials taught in Western classrooms in the late 1980s connected local experiences to other places usually through investigation of students' consumption choices—and by extension their complicity in damaging global supply chains that emerged from Western imperialism, colonialism and industrialization (34).The purpose of these investigations has been to show students how their daily purchases have global consequences on the environment and other communities. Critics like Annette Gaul claim that the global mindset encouraged in these learning materials systematically privileged Western (particularly American) perspectives and knowledge systems over other ways of knowing (qtd. in Gough 34).

Knowledge is culturally created through the collective learning of a unique community over time. Sandra Harding argues that social activities in local contexts derive new knowledge and this knowledge has inherent "cultural fingerprints" of the times and settings from which they emerged. Western science also has a "cultural fingerprint" but European imperialism gives this way of knowing "the *appearance* of universal truth and rationality" (qtd. in Gough 36). This causes science to appear culture-less because of its popularity and testability compared to other ways of knowing like indigenous teachings that are place-specific. Harding argues that the Eurocentrisim and androcentrism of science education curricula contribute to a kind of "scientific illiteracy" which is why the public does not perceive science as a social process (qtd. in Gough 36). According to Gough, acknowledging this critique is the first step in identifying the "blind spots" and "blank spots" that contribute to the "collective ignorance" of Western-enculturated environmental education research (38).

How then should students be taught to "think globally"? Gough suggests that Turnbull's spatial approach creates a comparison method for knowledge production because all knowledge originates locally (39). This validates ways of knowing that are communicated through art, ceremony, and ritual as well as the Western scientific discipline, allowing these traditions to coexist and complement one other. Global knowledge in and for environmental education should therefore encourage the representation of numerous local knowledge traditions instead of translating or exchanging local knowledge for a singular "universal discourse" (Gough 33).

GIS for Environmental Education

Place-based pedagogy reveals that global and local thinking are not mutually exclusive frameworks but intertwined and necessary to gain a more complex understanding of how earth systems and human culture—including economic, scientific, historical and political ways of knowing—shape each other. Geographic Information Systems (GIS), an integrated hardware and software system used to "manage, manipulate, analyze, model, and display geospatial data." This tool can be applied to help students better visualize these relationships which is why in 1994 the National Science Foundation organized the first US conference on GIS' pedagogical importance (Barnett et al. 332).

Geospatial tools facilitate multiple learning objectives through a five step geographic inquiry process. First, students choose a geographic question to explore. This question could be anything that can be referenced to a specific geographic location. For example, "Where do songbirds nest?" or "What does it matter if this whole area is cleared of trees?" or "What is the result of refugees moving from this land across the border to that place?" (ESRI Inc. 2003). Second, students acquire geographic resources to help them answer such questions. They have the ability to access real data used by scientists, government officials and business professionals and to collect and analyze this data depending on the assignment's parameters. They can learn spreadsheet data organization, data cleaning and editing (qtd. in Barnett et al. 333). The third step is exploring the geographic data by representing it as stacked feature layers (points, lines or polygons) and pictures (satellite or aerial imagery) on a map, in a chart or in a table. Students can decide how to visually represent their data by choosing different symbology for their map layers and by turning layers on and off to highlight different components.

The next step is analyzing the geographic information. GIS software has thousands of analytical tools but among the most helpful for K-12 students are the filter and query tools. Users can filter specific data or create a new layer based on the intersection of two or more layers. Applying a series of specifications, e.g. all the features within a five-mile radius or with a given elevation or slope, queries enable students to identify hidden patterns, correlations and relationships between their data (Barnett et al. 333). The final step of a geographic inquiry is to act on this new geographic knowledge. Students can use their maps to communicate compelling stories with their communities, using these representations of place to shape discussions about the meaning of place.

The education literature reveals that GIS can have many beneficial learning outcomes. Bransford and Gordin argue that the geoinquiry process teaches data manipulation and visualization skills which can increase students' ability to transfer new knowledge to novel situations and to understand components of complex science concepts and phenomena (qtd. in Barnett et al. 333). GIS is particularly useful for environment education that includes a scientific investigation of earth systems and biologic processes and a social-science approach to study how people impact the environment at local, regional and international scales. GIS can improve student understanding of distinct facts to ecological or social systems whether that be watersheds, land-use patterns, or political structures (Kerski 186). Geospatial technologies facilitate problem solving through the exploration of real world contexts and projects which the science education literature identifies as necessary for meaningful and useable understanding (qtd. in Barnett et al. 333).

GIS can engage students in a locally relevant topic that has a direct impact on their daily lives and it can be used for global thinking to visualize the "big picture" and to compare community and ecological characteristics in different places. Doering and Velestianos investigated the impact of engaging students in GIS analysis of real data through an adventure learning program. They found that students developed a "sense of place" and a more sophisticated understanding of the region's geography (qtd. in Barnett et al. 336). Sobel's studies revealed that students who collected field data and mapped it showed an enhanced connection to their local environment (qtd. in Kerski 22).Through resources like ESRI's Living

Atlas tool, students can examine a particular location or place from a variety of perspectives with relative ease and ask multi-dimensional questions about that place; something that was challenging or impossible just a few years ago due to lack of access to this technology outside of specialist use (Barnett et al. 332). An important purpose of environmental education is to empower students to understand and take action on environmental challenges that matter to them. Using GIS, students can model different scenarios and debate the potential consequences of their proposed solutions. By using these tools, students are not simply consuming this information but are actively producing and participating in new knowledge creation that can be shared with relevant policy makers and stakeholders (qtd. in Barnett et al. 334).

Internet-Based Case Study

Milson et al. conducted a qualitative study of ninth-grade geography students to observe how internet-based GIS use facilitated students' understanding of Africa's geography. The study took place at a diverse, metropolitan, public high school in which 48 percent of the students are considered economically disadvantaged. Their teacher had limited GIS experience and the school had laptop carts for student use. The pre-AP class was divided into teams and tasked with designing a presentation about the most significant issue facing their chosen African country or region. Over the course of eight class periods, they searched for data layers including population size and growth rates, life expectancy at birth, religions, literacy rates, climate, terrain, natural resources, electricity and oil consumption from a given database, uploaded it to a map, identified a problem and proposed a solution.

Interviews were conducted with the students to learn more about their experience, level of understanding and opinion about the exercise. The first finding was that students felt a sense of expanded freedom, because they weren't limited to their textbooks and could explore a variety of sources on the internet. One of the students remarked: "I liked being able to actually gather information in our own ways and put it together how we wanted" (qtd. in Milson et al. 232). Students also had the freedom to pick a geographic question and decide what kinds of data they would need to answer it. Allowing students to explore a topic interesting to them increased the effort they put into the activity. The teacher observed, "I have noticed that my Pre-AP kids are much more willing to seek out details to back up their assertions when they can express them visually. They are pulling out all the stops on creating maps and charts" (qtd. in Milson et al. 233).

Another finding from this study was that this kind of GIS application can increase students' cultural awareness and empathy for distant others. Students displayed empathy in different ways. Most students showed inferiorizing attitudes and proposed interventionist solutions like American military presence. One student remarked "send some delegate guys over there to set up a democracy and show-'em how it's done" (qtd. in Milson et al. 233). Other students were dissatisfied with the interventionist approach, but couldn't think of other options. Most students felt sadness for African people's suffering and a greater appreciation for the advantages of living in the US. Generally, students were not sure how to address the complexity of the problem. A student reflected: "we really don't know… how to help them—like *really* help them… 'cause it's like we are going to have to try and persuade people and all that" (qtd. in Milson et al. 233). A few students displayed cultural sensitivity and rejected the interventionist approach. Another student explained why his team's proposed solution was to mobilize local leaders: "They're from that area. They know what's going on… They can relate to it… I think it would be better to have someone else from there communicating with them rather than to send somebody in that doesn't even live there and has really no idea what they are going through" (qtd. in Milson et al. 234). The same students who proposed locally based solutions tended to recognize that the problems in the region were related: "We were like 'the solution is going to be easy'… And then once you figured out it was because of like a chain reaction you had to solve *all* the problems" (qtd. in Milson et al. 234).

From these observations, the authors concluded that internet-based GIS investigations were a helpful tool in introducing conversations about cultural sensitivity and empathy. They acknowledged that the interventionist approaches suggested by some white students was the product of a racist belief that African people cannot take care of themselves and require more educated and technologically advanced groups to fix their problems (Milson et al. 234). However, a majority of the students who participated in the exercise developed greater cultural awareness and empathy for the complexity of the problems. The authors acknowledged that the purpose of this kind of activity is not to convert students to a certain ideology, but to cause them to reject flawed concepts like cultural superiority (Milson et al. 234). These particular ninth graders were capable of this level of understanding. Another important note was that there was a need to teach students to consider the credibility of the data in the maps. In the digital age, part of digital literacy includes critiquing data sources.

Why Now?

In the 21st century, every student engages in our global society and economy in some capacity no matter their geographic location and context. This is why Kerski argues that current global trends and public access to data are making it possible for geospatial technology to be adopted in K-12 classrooms. Twenty first century challenges including population growth and migration, food security and anthropogenic climate change have been traditionally studied by geographers because they have spatial distributions, temporal components and patterns but have only entered public consciousness in the last few decades because of their immediacy and widespread consequences. The historic release of Google Earth in 2005 made it possible for people to manipulate digital maps online (DeBay et al. 236). Increasing geoenablement, the identification of nearly everything's location through GPS, is contributing to the emergence of the "internet of things" and "big data," increasing access to new kinds of data and technology (Kerski 15). In 2014, GIS technology began transitioning from a downloadable software program to a web-based format. Digital maps, imagery and geodatabases are increasingly used by the media, shared via social media and downloaded from websites, allowing public use in new ways. Through web-based citizen science, people can contribute their observations to global datasets. Web platforms like ESRI's Story Maps and Map Story (https://storymaps.arcgis.com/en/, https://www.mapstory.org/) provide ways for anyone to share geographic stories important to them, regardless of if they have computer programming skills.

GIS use in environmental education can prepare students for 21st century challenges and emerging careers designed to meet these challenges. There is an increasing need for tools in education to help teachers show the rapid changes our world is experiencing. Geospatial tools meet this need because they can model and predict change, use data that updates in real time and the tools themselves are updating as the technology improves (Kerski 186). Research shows that students who are trained in a spatial perspective think holistically and systematically, and may be better able to use data at different scales for different contexts, and to use quantitative and qualitative approaches for problem solving to become better decision makers (Kerski 22). GIS educators, researchers and practitioners recommend that geospatial technologies be “taught often, deeply and as inquiry through problem-based and project-based formats” (qtd. in Kerski 185). Because of the national emphasis on STEM (science, technology, engineering, and math), Nugent et al. explain that there is a new need for interdisciplinary, tech-based teaching methods including geospatial technology (qtd. in Kerski 188). In 1991, the Department of Labor’s “Partnership for Twenty-first Century Skills” identified that students need to acquire new skills to prepare them for careers in information technology and global business; in 2004, the Department of Labor listed geospatial technologies as a career in increasing demand (Kerski 190; Barnett et al. 333).

K-12 educators are adapting to these trends by gradually adopting geospatial tools that are increasingly compatible for classroom use. Yet reliance on an often limited number of information technology (IT) staff at K-12 schools has limited GIS’ adoption into schools. IT providers are understandably wary of downloading geospatial software packages that they have little experience working with and that require disk space and computing power. The evolution of web-based geospatial tools and applications removes this hurdle, and now that data, curriculum and maps can easily be shared online, there is less demand on teachers’ limited time. The timing is propitious because spatial thinking is being introduced into national education standards and geospatial tools specifically in some state standards that makes it easier for teachers to justify incorporating GIS (Kerski 189). Professional development opportunities to learn geospatial technology are becoming more accessible to educators through online courses and in-person trainings. There is a burgeoning number of geospatial education researchers and recent developments like the National Academy of Sciences 2006 "Learning to Think Spatially" report, the NSF supported Geography Roadmap project and the establishment of an online GIS education bibliography that have supported classroom adoption and methods. As a result of these efforts, Kerski claims that GIS adoption has moved past "innovators" and "early adopters" to the "early majority" of educators. He also attributes this increased in adoption due to the resurgence of inquiry pedagogy and because web-based GIS lowers the learning curve for educators by allowing use on any device instead of requiring individual software installations (Kerski 19).

Challenges of GIS Classroom Use

While there are numerous benefits of GIS use in education and exciting opportunities for its widespread use, the literature also acknowledges that there are significant barriers to classroom adoption of GIS. On the technological front, challenges include internet bandwidth, access and the cost of analytics as an internet service (Kerski 190). In a survey of educators in 33 countries, "access" was the most reported challenge including access to useable computers, disk space, and IT support. Even if schools have computer labs, Baker et al. report it can still be hard for teachers to get permission to use them (qtd. in Kerski 191). The open and big data movement is making it easier for teachers get data, but it can still be difficult to find local data with permissions for educational use (Kerski 191). It is also important to note that the increased access to data poses a need to teach data fluency, an understanding of the capabilities and limitations of data. While maps are powerful visualization tools, students must be taught to identify their limitations and distortions in terms of map projection, resolution, scale, attribute completeness and source credibility. Because of the emerging nature of this field, issues like copyright and privacy standards are still developing (Kerski 19).

There is also a lack of teacher preparation due to the steep learning curve. This is especially pronounced for educators with limited computer experience, because GIS software is mainly designed for professional use. GIS requires advanced skills like data cleaning and conversion to be suitable for classroom formats. Between tech-anxiety amongst teachers, and institutional pressure to focus on standardized test objectives and content-transmission pedagogies, significant obstacles to broad adoption remain.

Place-Based Education Example: Jane Goodall Institute's Roots & Shoots

The literature also states that there is a need to design methodology for assessment of these tools (Barnett et al. 3444). One environmental education approach that tackles this issue and recognizes the benefits of teaching place through geospatial tools is Dr. Jane Goodall's Roots & Shoots program. In 1991, Dr. Jane Goodall formed the first Roots & Shoots group with 12 Tanzanian teenagers to develop solutions to social and environmental problems facing their neighborhood. Today, Roots & Shoots is a youth-led program in nearly 100 counties. Its mission is to empower young people to make a difference for people, other animals and the environment. Their service learning curriculum is easy for educators to use in the classroom because lesson plans are aligned to Common Core State Standards in the United States. Service learning is a teaching pedagogy that connects curriculum to meaningful service opportunities.

The Roots & Shoots program objectives are to:

- Create purposeful learning
- Build a sense of civic responsibility
- Enhance critical-thinking skills
- Foster career exploration
- Encourage students to become positive change agents

These outcomes are met through the four step service learning model:

1. Engage- Getting Started & Engaging Young People

2. Map your community- Making Observations & Defining Your Campaign

3. Take Action- Prioritizing Community Needs & Planning Your Campaign

4. Celebrate- Recognizing Success & Celebrating Impact

Step 2, “Map Your Community” is a place-based teaching methodology that Roots & Shoots educators use because it is applicable and can be adapted to be culturally relevant for any location. Roots & Shoots uses community mapping because it recognizes that spatial visualization allows young people to apply their environmental science knowledge and unique cultural perspectives and identities to prioritize and act on real problems in their community. The Jane Goodall Institute’s conservation scientists also use community mapping in Africa to “incorporate local, indigenous knowledge into the creation of conservation and development projects around chimpanzee habitats” (*Jane Goodall’s Roots & Shoots*).

The community mapping process teaches students about their community's geography, characteristics and features. From these observations, students get a better understanding about what makes their community special, the distribution of needs for people, animals and the environment and the location of resources that can be tapped to help meet these needs. From an academic perspective, community mapping intersects with social studies, geography, math and English/language arts subjects. The community mapping process can take between two hours to multiple days depending on the teacher's needs. It can be adapted for K-12th graders and completed through pen and paper or web-based mapping tools like ArcGIS Online or Google My Maps. Interviews with community leaders, audio, pictures and video can supplement the maps. After completing the program, 82 percent of teachers reported that their students demonstrated an awareness of issues facing their community; 90 percent noted that the majority of their students demonstrated an awareness of the interconnectedness between people, animals and the environment; and 90 percent reported that the majority of their students demonstrated compassion toward people, animals and the environment (*Jane Goodall's Roots & Shoots*).

In 2013, Roots & Shoots incorporated the emergence of online spatial tools by making a digital version of its community-mapping tool. The organization contracted with a third-party evaluator and incorporated feedback to improve the new online community mapping version. Educators reported that through community mapping, 61 percent of the resulting service campaign was entirely youth led. Sample service learning projects included graffiti removal, food waste reduction and bike lane campaigns. Before mapping their community, zero percent of students were aware of the connectivity of people, animals and the environment;

afterwards, 100 percent of students gained some amount of awareness with 58 percent representing a high level. The survey responses revealed that the students appreciated the activity because they could apply their individual skillset and felt it was a meaningful way to demonstrate STEAM (Science, Technology, Engineering, Arts, and Math) subject knowledge, with many showing an interest in teaching others how to make community maps (*Jane Goodall's Roots & Shoots*).

The Roots & Shoots community mapping model is an excellent example of place-based education because it empowers students to take action as the experts of their communities. Given that the majority of GIS use in the American classrooms focuses on local community investigations, my thesis contributes to the literature because it is a geographic inquiry centered on a community abroad, using emerging geospatial tools like ESRI's Story Maps and GeoPlanner (Barnett et al. 334). In particular, there is no other documented use of GeoPlanner in a high school classroom context. I specifically incorporated this tool because it introduces students to the concept of weighted modeling and gives them the ability to model potential land use scenarios and the related impacts on human and animal communities from those decisions. I argue there is a need for curricula that is culturally sensitive and international place-based to prepare students to holistically address global, 21st century problems such as anthropogenic climate change, the refugee crisis and species extinction.

Environmental educators must encourage culturally conscious, systems and spatial thinking to help students understand the impact of their values and roles as consumers, advocates and citizens in their unique communities and in the world at large. My lesson plan is a resource for Roots & Shoots educators and the larger environmental education community because it shows students how conservation scientists incorporate local cultural knowledge, ecology and geospatial tools to design effective land use plans. This case study's location, the Greater Gombe Ecosystem in western Tanzania, is one of the most famous conservation sites in the world. In 1960, through the support of Dr. Louis Leakey, a young Jane Goodall with no formal scientific training, traveled there to conduct the first study of chimpanzees in the wild. Her pioneering observations of chimpanzee behavior revealed that they are toolmakers, capable of primitive warfare and have feelings and identities, all qualities thought to be uniquely human.

Recognizing the need to ensure the long-term survival of chimpanzees in the wild through habitat conservation, Dr. Jane Goodall founded the Jane Goodall Institute in 1977. The organization's revolutionary community-centered conservation strategy demonstrates how conservation projects can engage local people and incorporate their culture and ways of knowing to create equitable and sustainable outcomes. The inclusion of culture in conservation planning further emphasizes how environments are culturally produced which is a key component of place analysis. This is an essential approach to teach students, who may believe that interventionist strategies (as documented in Milson et al.'s case study) are necessary to solve development challenges. My hope is that students will better comprehend the characteristics of equitable, sustainable conservation after exploring the Jane Goodall Institute's community-mapping model and its relation conservation-action plans.

Chapter 3: Lesson Plan

Background Information

To reach as many students as possible, it was necessary to address the challenges of GIS' application for the classroom. The format of the lesson is web-based to maximize accessibility, requiring no software downloads. Although the analytical GeoPlanner activity requires that each student have an ESRI organizational account, this is a free resource through ESRI's "ConnectEd Initiative": http://www.esri.com/connected. Accounting for the varying levels of GIS experience that teachers may possess, the bulk of my lesson is formatted in an ESRI Cascade Story Map. This tool only requires an internet connection to access and it can host satellite imagery, videos, photos and maps. This lesson is optimal for a teacher who wants to introduce any of the included environmental science vocabulary within a real-world, well-known conservation context.

The lesson guides students through place-based inquiries with opportunities to incorporate observations of their unique community to the communities and ecosystem outside of Tanzania's Gombe National Park. It is aligned with the national AP Environmental Science standards so that the activities can be woven into preexisting topics that environmental educators are already teaching. Because it can be time consuming for teachers to find reputable data, get permission to use it, and convert it into a usable classroom format, I have included the data in this lesson to minimize the preparation time and GIS skills needed to facilitate the exercise. I have also included answer keys to the analytical problems that the JGI team has reviewed to ensure its accuracy.

My lesson plan is in part a response to the gaps outlined in the *Call for an Agenda and Center for GIS Education Research*, an article summarizing the body of research surrounding GIS in education (2012). It outlines the need for a formalized research agenda and presents topics for further study. The authors described six research gaps in the GIS education field and my thesis best aligns with the fourth of these, what the authors identify as "Citizenship formation through GIS use." In particular, two research questions "What difference does the use of GIS have on how students perceive the world, their country, their region and their community?" and "What impact does GIS have on student attitudes about their own role in society and about environmental issues?" are key questions that student feedback gleaned from the assessment component of my lesson can attempt to answer (Baker et al. 273). Given the relative newness of the GIS education field, best practices are still being developed for effective GIS curricula design. There are no official standards or formats with which to align my thesis, so I have modeled my lesson plan on the curricula that ESRI's Education Team has designed. ESRI is the GIS industry leader and this team includes some of primary thought leaders and founding individuals who began applying GIS for classroom use. I am hopeful that my GIS environmental science lesson can contribute to the growing body of GIS curricula for secondary school use which future research can compare and evaluate.

Lesson Plan

The purpose of this mapping activity series is to learn how ecology and community knowledge can be incorporated into sustainable and equitable conservation strategies. Each map is accompanied by a set of geographic inquiries with key vocabulary, analysis activities and discussion questions for students to complete. There are activities with beginning and intermediate difficulty levels to meet the needs of teachers with varying GIS comfortability levels and classroom time:

- The mapping inquiry activities can be found in the story map: http://arcg.is/2f3j7qv that only requires internet access to operate. This activity is appropriate for an educator with limited to beginner GIS experience.
- Activity 2 is an additional analysis investigation through GeoPlanner that requires an Esri organizational account and an internet connection to operate. This activity is challenging and is appropriate for educators with intermediate to advanced GIS experience.
- There is an additional document containing recommended readings for teachers to assign for homework emphasizing the environmental science concepts included in the lesson plan. The reading topics include national examples of habitat corridor projects, geodesign and JGI's community-centered conservation strategy, a study of the ecosystem services provided by tree species outside of Gombe National Park, and an article about habitat fragmentation in the Amazon.

Target Audience: EP Environmental Science students, 11-12th grade

Mapping Activities and Corresponding AP Environmental Science Standards (APES):

Maps 1 & 2: Chimpanzee range loss and Human Population Growth

- APES III B. Human Population
- APES IV G. Global Economics

Map 3: Ecosystem Services

- APES II C. Ecosystem Diversity

Map 4 & 5: Culture and Community Mapping

Map 6: Land Use Planning

- APES IV D. Other Land use

Map 7: Habitat Corridor and Biodiversity Benefits

- APES III A. Population Biology Concepts

Map 8 & 9: Soil Conservation and Water Quality

- APES I D. Soil and Soil Dynamics

Map 10 & 11: Reforestation

- APES IV B. Forestry

Learning Outcomes:

- Learn environmental science vocabulary through map exploration: **ecosystem services**, **tragedy of the commons**, **habitat corridors** and **community mapping**
- Analyze webmaps to understand basic chimpanzee biology, human community demographics, and the cultural and geographic context surrounding Gombe

- Watch media of community members, JGI’s conservation scientist and Dr. Goodall to observe how stakeholder’s interests are recognized in community-centered conservation and the impact of this strategy (through satellite imagery comparison)
- Use GeoPlanner to design land use scenarios that meet the needs of the human community, chimpanzees and gorillas given fixed criteria

Text References:
The concepts taught through the mapping activities have been cross-referenced to material from Environmental Science for AP by Friedland and Relyea and Living in the Environment by Miller.

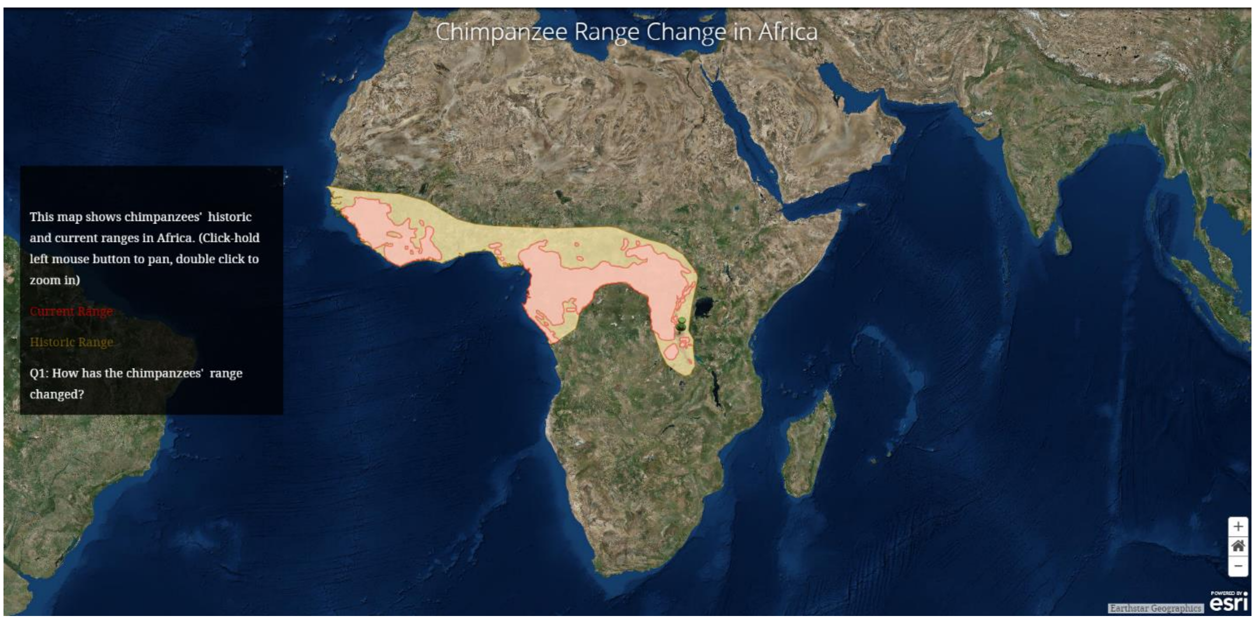
For Teachers: **Print Version of Story Map “An Introduction to Community-Centered Conservation: Exploring the Ecology and Culture of Gombe’s Greater Ecosystem”**

In July 1960, 26-year-old Jane Goodall arrived at Gombe Stream Reserve in what is now Tanzania, to attempt the first study of wild chimpanzees. Her groundbreaking discovery that chimpanzees make and use tools, challenged the very definition of humans, who were thought to be the only toolmakers. Her research also revealed that chimpanzees have personalities and emotions, qualities also thought to be uniquely human.

Three decades later, Dr. Goodall and her team continued studying chimpanzee behavior at Gombe. Flying over the national park, Dr. Goodall observed a troubling fact: the forests surrounding Gombe had been chopped down, leaving bare and eroded hills. Over 65 percent of the chimpanzee habitat outside Gombe was lost.

Today, fewer than 300,000 individuals live in the wild.

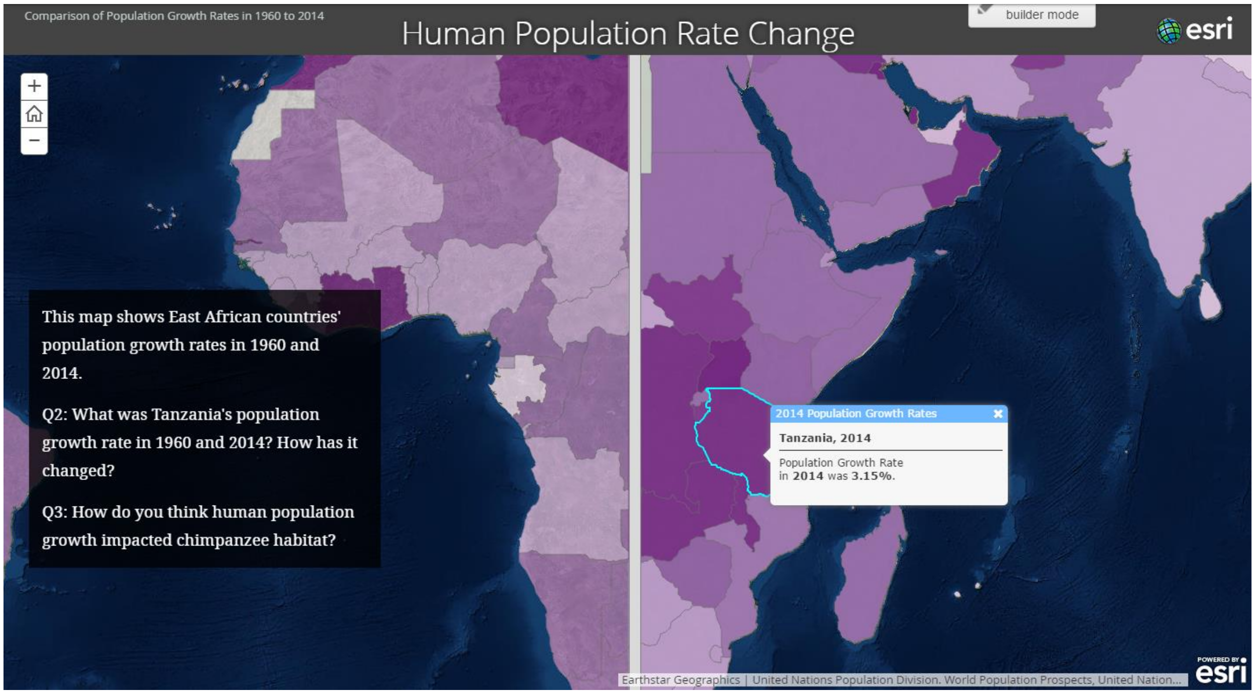
Map 1: This map shows chimpanzees' historic and current ranges in Africa.



Q1: How has the chimpanzee range changed?

To meet the needs of Africa's growing population, more than 10 million acres of forests across the continent are cleared every year for human settlements and agriculture.

Map 2: This map shows African countries' population growth in 1960 and 2014.



Legend

1960 Population Growth Rate by country	2014 Population Growth Rate by country
Population Growth Rate	Population Growth Rate
3 to 14%	3 to 14%
2 to 3%	2 to 3%
1 to 2%	1 to 2%
0 to 1%	0 to 1%
-1 to 0%	-1 to 0%
-2 to -1%	-2 to -1%
-10 to -2%	-10 to -2%
no data	no data

Q2: What was Tanzania's population growth rate in 1960 and 2014? How has it changed?
Q3: How do you think human population growth has impacted chimpanzee habitat?

<u>Forest Loss and Human Population Growth</u>

Chimpanzees' remaining forest habitat is threatened by conversion to agriculture, logging, charcoal production, and livestock grazing.

The reason publicly-managed forests often become degraded is because they are unregulated **common-property resources** available to everyone. Other examples of common-property-resources are fish stocks and our global climate.

In 1968, biologist Garret Hardin explained that in deciding how much of a common resource to use, everyone assumes "If I don't use this resource, someone else will. The little bit I use or pollute is not enough to matter." With a small number of uses, impacts are small, but the cumulative consequence results in a **tragedy of the commons scenario** in which the individual uses of a common resource for personal gain degrades the resource to an unsustainable level of *depletion or degradation. (qtd. in Miller 226)*

Think about **tragedy of the commons** this way: if your family shares one cellular data plan, what happens if each person acts in their self-interest? You might use a lot of data, fearing that your sibling might use it if you don't first. It is likely that your family's data use will exceed the allotted amount and you'll get charged a fee.

Community-Centered Conservation

Concerned that habitat loss would drive chimpanzees to extinction, Jane realized: "No white people [could march in, puffing themselves up and say "You've made a mess; we're going to put it right]." "Only if people living around the wilderness areas like Gombe become our partners can we hope to save the habitat and animals who live there."

Watch the video below to learn how the Jane Goodall Institute and their local community partners use geospatial technology and community mapping for sustainable land management and development in the Greater Gombe Ecosystem:
https://www.youtube.com/watch?v=Xh8Mj4vgotk

The full length Google Earth Outreach video can be found here: https://youtu.be/CNXv8EEs0P8

Task: You have been hired by your city council to design a conservation strategy for the community using what you will learn from the Jane Goodall Institute's approach. The following maps will pose a series of important questions to consider and lessons to give to ideas.

Why are forests important?

Before proposing any changes to a community, it is important to first investigate how the landscape is working well for people, animals and the environment. **Ecosystems services** are the cultural, environmental and economic benefits and resources that an ecosystem or species produces.

Map 3: This map shows the ecosystem services provided by tree species in the Greater Gombe Ecosystem. Click on the pins to discover how different tree species benefit people, animals and the environment. Record in the table below your findings.

The different green shades represent the different habitat types in the ecosystem: evergreen woodland, deciduous dry forest, miombo woodland and grassland. Different tree species grow in different habitat that depend on geologic factors like elevation and soil type.

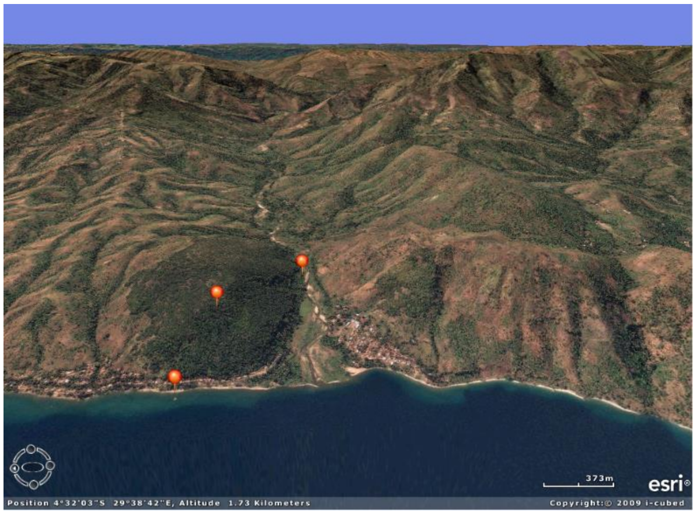
Tree Species and common name/local name if given	Benefits for people	Benefits for animals	Benefits for the environment

Q5: How does the Jane Goodall Institute work with villages to establish sustainable livelihoods?
Q6: How do chimpanzees use trees?
Q7: Name three tree or plant species found near you. What are their benefits to people, animals, and the environment?

Why does local culture matter?

Conservation scientists use satellite imagery to monitor landscape change like forest loss and forest growth. Below is an image of a village outside of Gombe.

Q8: Write a hypothesis for why you think the forest patch in the bottom left of the picture is intact, while the surrounding hills have been deforested.

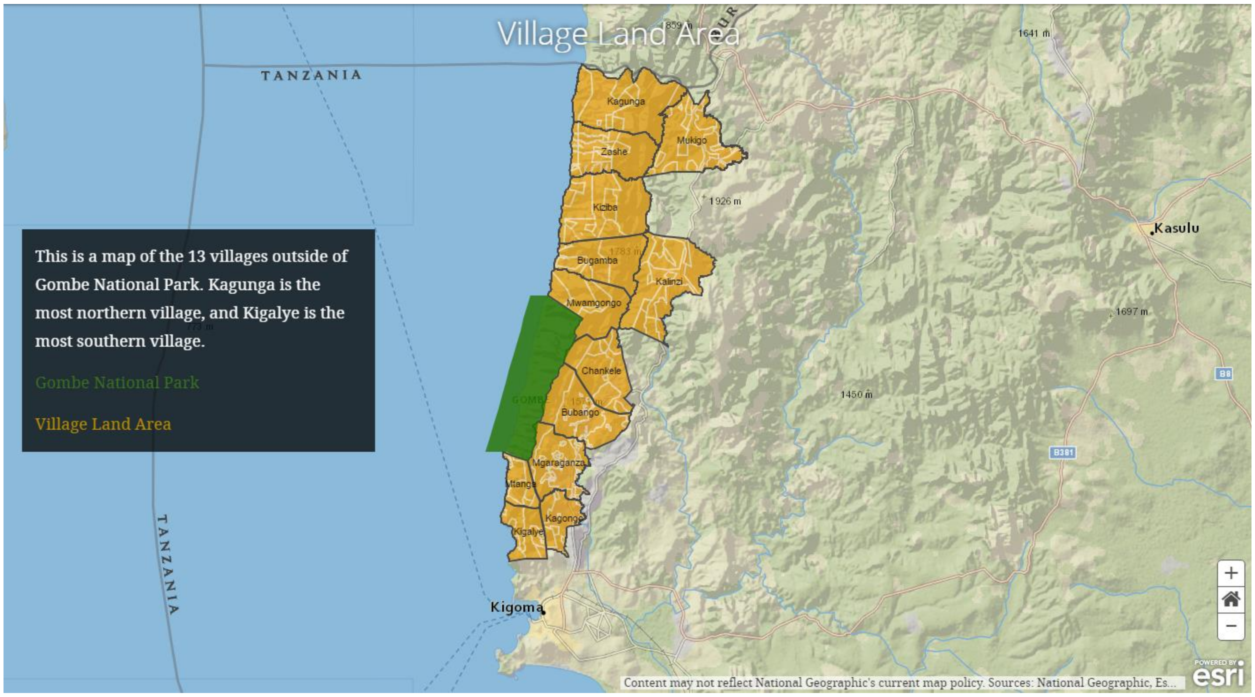


Satellite imagery reveals temporal landscape change, but it cannot answer WHY this change happens. The only people who can answer this question are community members from that specific place. Villager protected the forest patch because it contains three sacred sites (represented by the orange pins above); the rest of the forest was cleared in a classic tragedy of the commons scenario.

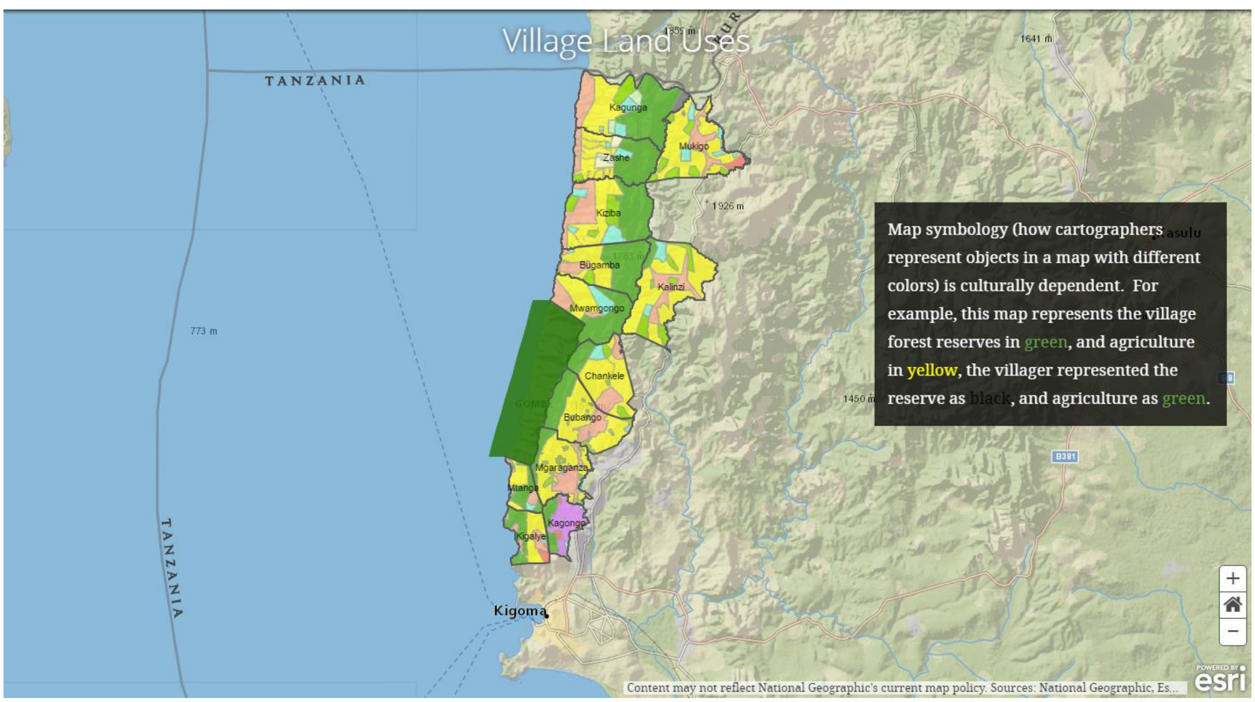
Conservation scientists use a tool called **community mapping** to work with local communities to identify locations of ecological and cultural significance, including sacred sites and wildlife habitat. This participatory process is an especially important method for international conservation work because it is important to recognize and respect that local people are the experts of their environment.

Q9: What places hold cultural or spiritual significance to you in your community? Why?

Map 4: This is a map of the 13 villages outside of Gombe National Park. Kagunga is the most northern village, and Kigalye is the most southern village.



Map 5: This map shows how the land is allocated to be used in the 13 villages.



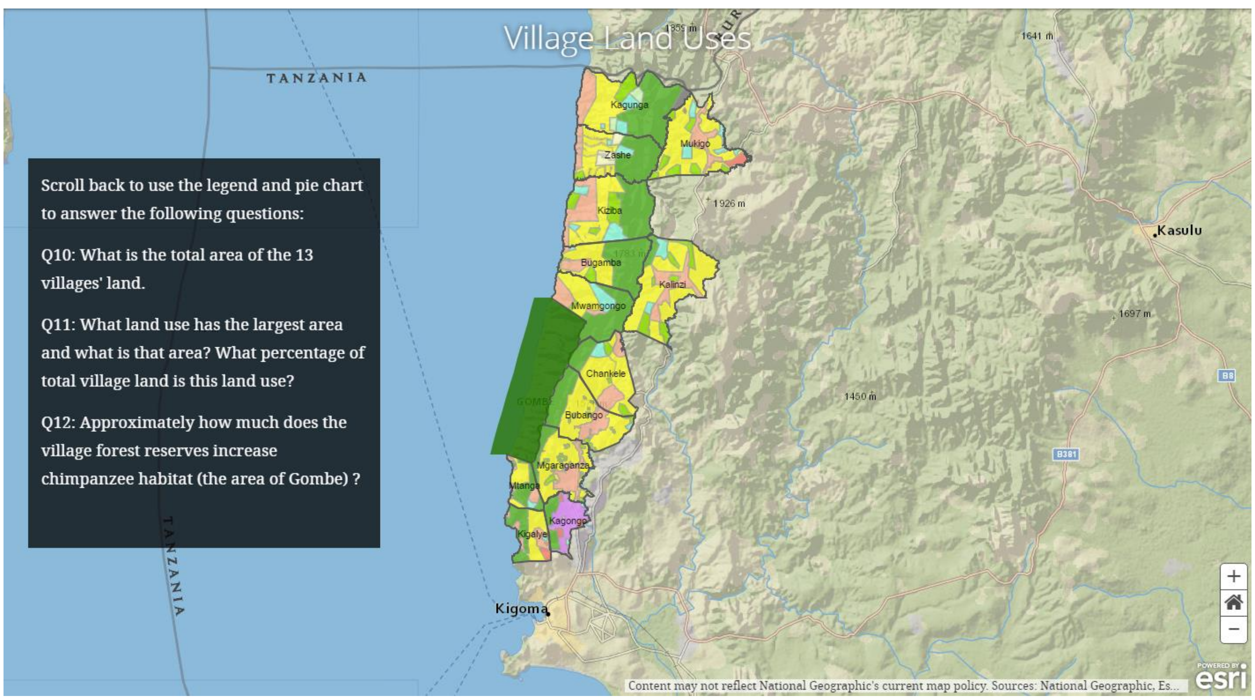
Q10: How is the map of Kigalye village colored differently than this drawing of the same area by a Kigalye villager?

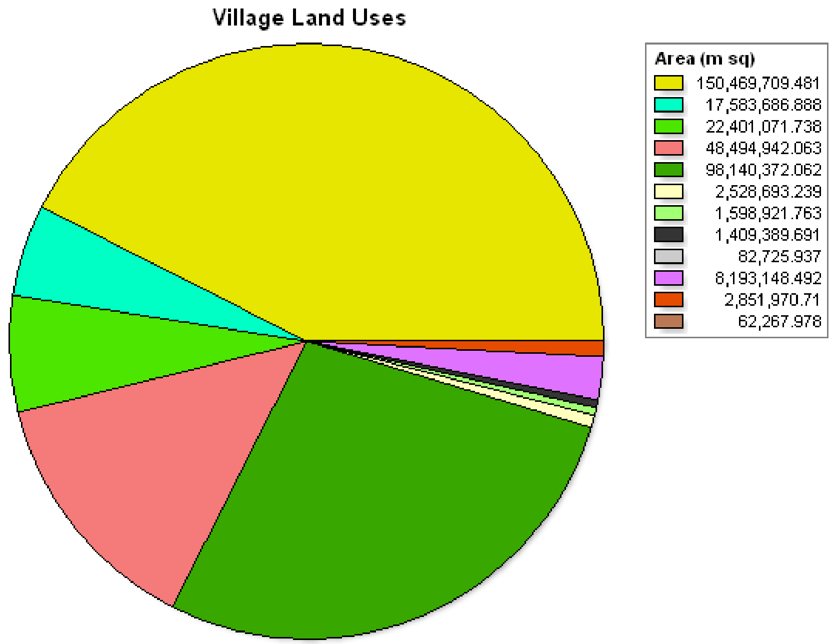
Map symbology (how cartographers represent objects in a map with different colors) is culturally dependent. For example, this map represents the village forest reserves in green, and agriculture in yellow, the villager represented the reserve as black, and agriculture as green.

Land use planning is a method for deciding how land should be developed and managed. Using a mapping software called geographic information systems (GIS) it is possible to overlay a map with different geological, ecological, wildlife and sociological data to model and ecosystem and human community.

Mtiti is the Jane Goodall Institute Director in charge of facilitating land use planning in Tanzania. He explains the process, “The village management teams lay out their plans by creating a simply diorama on the ground using sticks, stones and leaves to make out different land use areas in the plan.” Then district surveyors visit the village and digitize the diorama plan using GPS coordinates. The Jane Goodall Institute plots the GPS coordinates on the map with satellite imagery. The final map is shared with and endorsed by the village and then sent to the Ministry of Natural resources to ensure that the “by-laws are legal and protected by the courts.”

Map 6: This map shows the 12 different land use types.



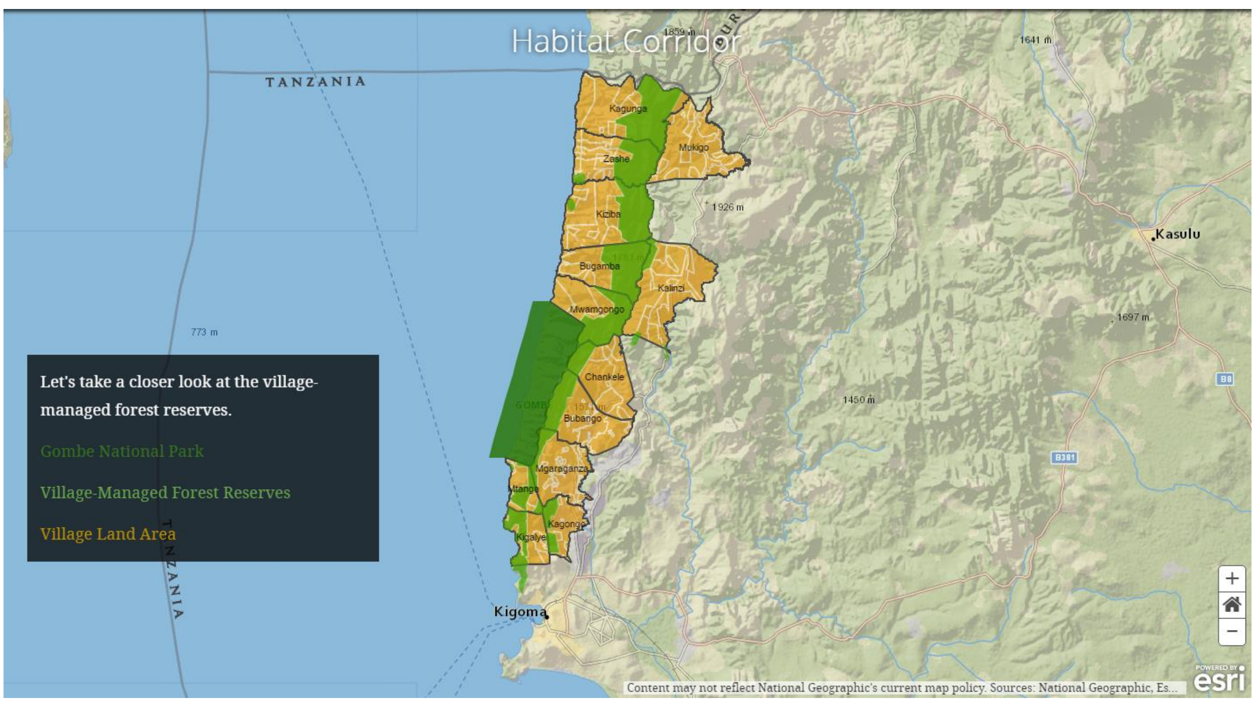


Scroll back to use the legend and pie chart to answer the following questions:
Q11: What is the total area of the 13 villages' land in sq km? Don't forget units! (1 m sq = 1 * 10^-6 km sq)
Q12: What land use has the largest area and what is that area in sq m? What percentage of total village land is this land use?
Q13: Approximately how much does the village forest reserves increase chimpanzee habitat?

How did the villages choose the location for the forest reserves?

As conservation partners, every village outside of Gombe National Park decided to restore and conserve some of the forest on their land through a forest reserve. Through sustainable land-use planning, village-managed forest reserves, if restored, nearly doubled the size of available habitat for chimpanzees.

Map 7: This map shows the village-managed forest reserves.



When a landscape is developed for human purposes, the remaining habitat becomes fragmented. If habitat patches are surrounded by human land uses, they become isolated and animals may be unable to travel between them. This could cause inbreeding and increased risk of extinction.

The connecting village reserves serve as a habitat corridor for wildlife. **Habitat corridors** are used to connect habitats that have been fragmented by human development.

The village-managed forest reserves benefit chimpanzees by creating habitat corridors within the Greater Gombe-Masito-Ugalla ecosystem. But how do they help people?

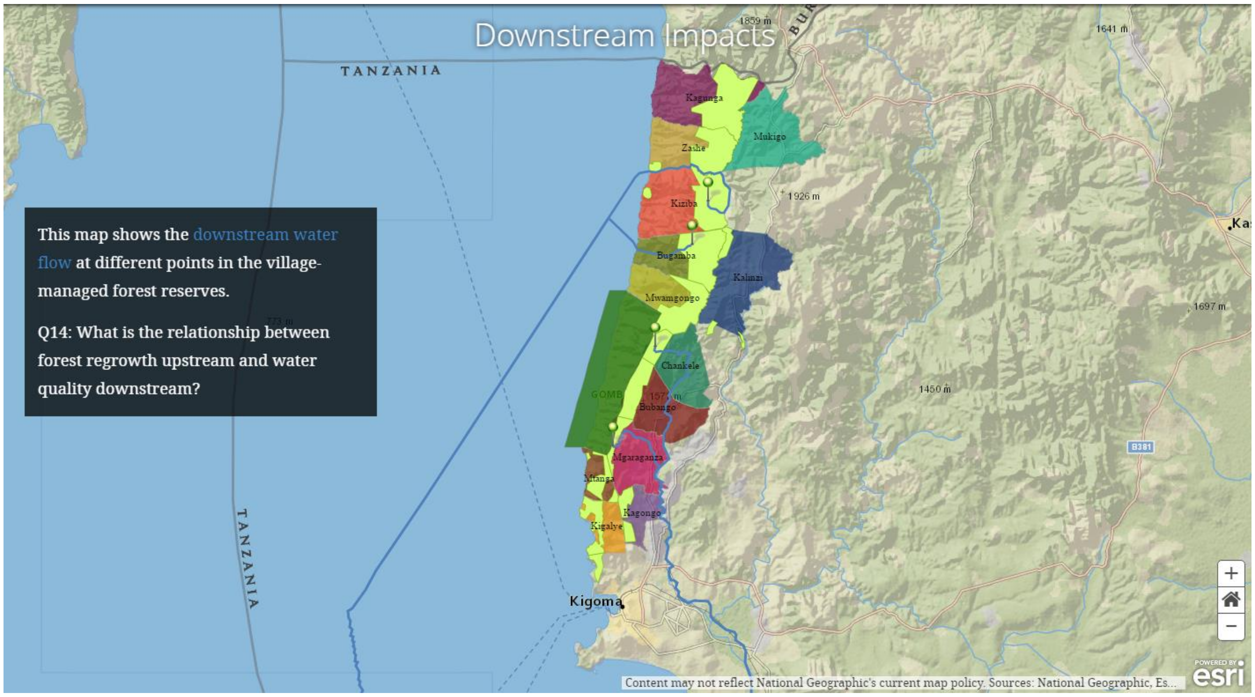
Before the village forest reserves were established, as much as 90% of the vegetation had been cleared in the Greater Gombe Ecosystem watersheds. Deforestation caused soil erosion and depleted nutrient-rich topsoil which decreased agricultural yields. Soil accumulated into waterways, damaging the watershed. Numerous landslides destroyed agriculture fields and habitat. One large landslide in 2001 killed several people.

Map 8: This 3D map shows the village-managed forest reserves.

Q14: Why do you think the forest reserves were designated along a ridge with high elevation?

The village-managed forest reserves were placed along the hills’ ridges to prevent erosion. The trees’ roots hold the soil in place. Hills and mountains are prone to high erosion rates because of their steep slopes.

Map 9: This map shows the downstream water flow at different points in the village-managed forest reserves.



Q15: What is the relationship between forest regrowth upstream and water quality downstream?

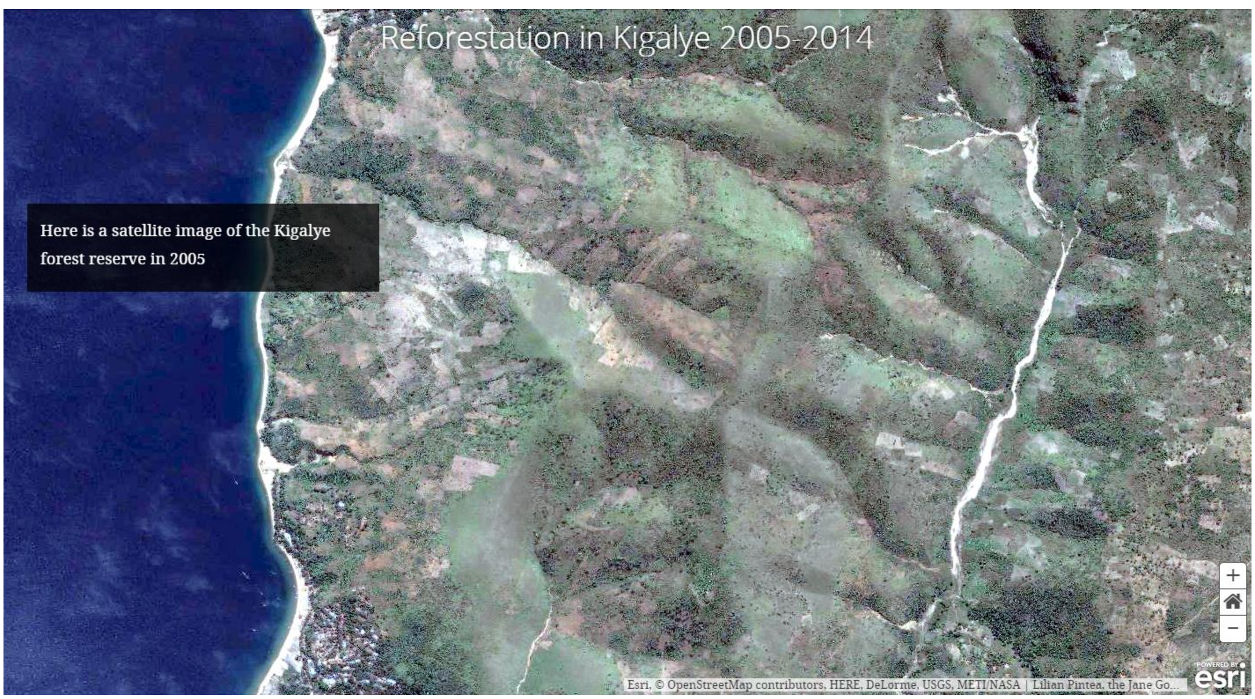
Maintaining healthy forests upstream improves water quality downstream. This is important because most of the villages rely on spring water downstream for their drinking water. Clear, clean water downstream supports healthy fish populations that is a major food source for people and wildlife.

<u>How do we monitor success?</u>

The Jane Goodall Institute uses very high resolution satellite imagery and drone imagery to monitor the village-managed forest reserves.

It is estimated that 126 hectares of forest has regrown since 2005 in the Kigalye village forest reserve. The total forest cover in 2014 was approximately 282 hectares, or 76% of the original forest cover in 1972.

Map 10: This is a satellite image of the Kigalye forest reserve in 2005.



Map 11: This is a satellite image of the Kigalye forest reserve in 2014.

Sustainable land use planning has improved the quality of life for people and increased the amount of habitat. Forests in some of the village-managed forest reserves are returning. Kigalye village's chairperson Kasalla reflected "We have peace of mind when we go to sleep during the rainy season. Our school that was gradually being eroded from flooding, is now stable. We are now working toward controlling illegal hunting. We are now seeing wildlife and birds coming back. We are proud because this is all from our success." Effective conservation strategies meet the needs of people and animals.

Mapping Activity Questions for Students

Q1: How has the chimpanzee range changed?

Q2: What was Tanzania's population growth rate in 1960 and 2014? How has it changed?

Q3: How has your community changed in your lifetime? Think about your community's development, demographics and environmental trends.

Q4: How do you think human population growth has impacted chimpanzee habitat?

Tree Ecosystem Services Chart

Tree Species and common name/local name if given	Benefits for people	Benefits for animals	Benefits for the environment

Q5: How does the Jane Goodall Institute work with villages to establish sustainable livelihoods?

Q6: How do chimpanzees use trees?

Q7: Name three tree or plant species found near you. What are their benefits to people, animals, and the environment?

Q8: Write a hypothesis for why you think the forest patch in the bottom left of the picture is intact, while the surrounding hills have been deforested.

Q9: What places hold cultural or spiritual significance to you in your community? Why?

Q10: How is the map of Kigalye village colored differently than this drawing of the same area by a Kigalye villager?

Q11: What is the total area of the 13 villages' land.

Q12: What land use has the largest area and what is that area? What percentage of total village land is this land use?

Q13: Approximately how much does the village forest reserves increase chimpanzee habitat?

Q14: Why do you think the forest reserves were designated along a ridge with high elevation?

Q15: What is the relationship between forest regrowth upstream and water quality downstream?

Assessment

1. Explain how the individual use of common property resources often leads to a tragedy of the commons scenario.

2. What are some important ecosystem services provided by trees for people, animals and the environment?

3. What is one tool that conservation planners use to incorporate the expertise of local communities?

4. As a conservation planner, what kind of data would you collect about a species to help you better protect it? (its range, habitat, and what it eats)

5. As a conservation planner, why is it important to understand the local ecology of a place?

6. Why is it important to understand the local culture?

7. In designing your conservation strategy, who are the stakeholders you would consult and partner with? Why?

8. How would you measure the success of your conservation plan?

Mapping Activity Question Answers

Q1: How has the chimpanzees' range changed?
Chimpanzees' current ranch is much smaller than their historic range.

Q2: What was Tanzania's population growth rate in 1960 and 2014? How has it changed?
The growth rate in 1960 was 2.89%. The growth rate in 2014 was 3.15%. It has increased .26%.

Q3: How has your community changed in your lifetime? Think about your community's development, demographics and environmental trends.
This could be anything related to the local community.

Q4: How do you think human population growth has impacted chimpanzee habitat?
An increase in human population has resulted in the degradation of chimpanzee habitat as people use forest resources unsustainably.

Q5: How does the Jane Goodall Institute work with villages to establish sustainable livelihoods?
Villagers are trained in agroforestry and they plant tree nurseries.

Q6: How do chimpanzees use trees?
Chimpanzees build nests in trees for protection from predators, parasites, biting-insects and insulation. They also eat fruit and leaves for medicinal purposes.

Q7: Name three tree or plant species found near you. What are their benefits to people, animals, and the environment?
These answers will depend on the specific tree or plant species found within your community.

Q8: Write a hypothesis for why you think the forest patch in the bottom left of the picture is intact, while the surrounding hills have been deforested.
This could anything related to forest use.

Q9: What places hold cultural or spiritual significance to you in your community? Why?
This could be a temple, cultural center, museum etc.

Q10: How is the map of Kigalye village colored differently than this drawing of the same area by a Kigalye villager?
The map represents the village forest reserves in green and agriculture in yellow. The villager represented the reserve in black and agriculture in green.

Q11: What is the total area of the 13 villages' land in sq km? Don't forget units! (1 m sq = 1 * 10^-6 km sq) *353,816,900 m sq = 353.8169 km sq.*

Q12: What land use has the largest area and what is that area in m sq? What percentage of total village land is this land use?
Agriculture is the largest land use. Its total area is 150,469,709.461 m sq, or about 43% of total village land use.

Q13: Approximately how much does the village forest reserves increase chimpanzee habitat?
Gombe's area is 56,408.376.60 m sq and the village forest reserve's area is 98,140,372.06 m sq, so the reserves nearly double the available habitat for chimpanzees.

Q14: Why do you think the forest reserves were designated along a ridge with high elevation?
This could be anything.

Q15: What is the relationship between forest regrowth upstream and water quality downstream?

Forest regrowth upstream improves water quality downstream because erosion is reduced.

Tree Ecosystem Services Chart Handout Answers

Tree Species and common name/local name if given	Benefits for people	Benefits for animals	Benefits for the environment
Ficus Sur (broom cluster fig)	People use this species for fruit	Chimpanzee food source	Trees produce oxygen, provide flood control and habitat for species, store carbon, regulate climate and prevent erosion
Anisophyllea boehmii (mashindwe)	People use this species for timber, fruit and firewood	Chimpanzees eat mashindwe fruit	See above
Celtis mildbraedii (elm)		Chimpanzees eat elm bark to fight bacterial infections	See above
Brachystegia spp.	People use this species for firewood	Chimpanzees eat the seeds and leaves of this tree	See above
Cordia africana	People use this species for furniture, fruit and timber	Chimpanzees eat Cordia fruit, flowers and stems to reduce the effects of tuberculosis	See above
Vernonia spp. (mfumya)	People use this species to treat malaria and for timber, fruit and firewood	Chimpanzees eat Mfumya leaves to treat stomach aches and parasites	See above
Elaeis guineensis (oil palm)	People harvest oil palm fruit and	Chimpanzees eat oil palm fruit	See above

	crush it to make palm oil		
Uapaca kirkiana (sugar plum)	People use this species for fruit, timber, firewood	Chimpanzees eat sugar plum fruit	See above
Ficus sansibarica (knobbly fig)		Chimpanzees eat unripe figs because they have deworming properties	See above

Assessment Answers

1. Explain how the individual use of common property resources often leads to a tragedy of the commons scenario. *Each person uses the resource thinking that if they don't take advantage of it, another person will. If enough people act in their self-interest, the common property resources are consumed to the point that they are degraded or exhausted.*

2. What are some important ecosystem services provided by trees for people, animals and the environment? *Trees produce oxygen and store carbon (preventing it from being released from the atmosphere and contributing to climate change). People use wood for furniture and firewood. Animals build nests in trees and eat fruit from the trees.*

3. What is one tool that conservation planners use to incorporate the expertise of local communities and how does it work? *Conservation planners use community mapping to incorporate the insights of local communities who can identify locations of cultural and ecological significance.*

4. As a conservation planner, what kind of data would you collect about a species to help you better protect it? *I would collect range, habitat and diet data. I would also find sociological data related to the human threats to this species.*

5. As a conservation planner, why is it important understand the local ecology of a place? *Knowing the local ecology of a place helps conservation planners make better decisions in terms of where to prioritize areas to conserve. For example, locations that have greater biodiversity or a water resource.*

6. Why is it important to understand the local culture?
Local culture can explain the characteristics and history of a landscape. It can explain why things are the way they are.

7. In designing your conservation strategy, who are the stakeholders you would consult and partner with? Why?
   I would partner with other conservation organizations that have different sets of expertise, city planners, ecologists, and community members whose land I was proposing to conserve.

8. How would you measure the success of your conservation plan?
   I would conduct a survey to see how community members felt about my plan. I could also conduct pre and post surveys to measure species presence/absence. Using satellite imagery, I could assess if the landscape became more degraded or restored.

Grading Rubric for Assessment

	3	2	1
Answers questions clearly and thoughtfully	Accurately explains	Explains with some accuracy	Explains with limited accuracy
Qualifies answer with examples	Examples are personal, detailed and creative	Examples are directly from the mapping activities and creative answers are lacking to localized questions	Examples are limited and copied directly from the mapping activities
Answers demonstrate holistic systems thinking	Explanations show understanding of interconnectedness between people, animals and the environment	Explanations show limited understanding of interconnectedness between people, animals and the environment	Explanations show no understanding of interconnectedness between people, animals and environment

GeoPlanner Activity

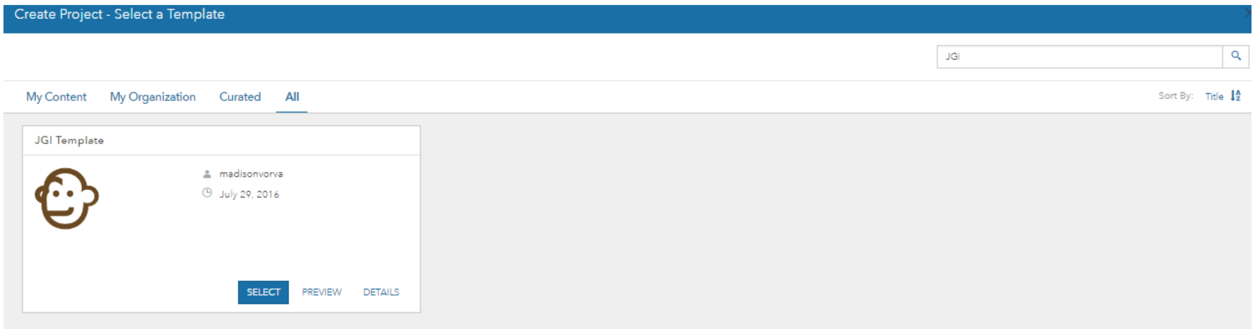
Activity: This activity introduces weighted suitability modeling analysis as a method for identifying optimal locations for different land uses. Students are tasked to design a habitat corridor given some ecological and social criteria.

Background Information:
It’s time to put your conservation knowledge and GIS skills to the test. A conservation organization has hired to you design a wildlife corridor connecting two national parks together in the Democratic Republic of Congo.

1. Login to GeoPlanner using your ESRI organizational account: geoplanner.arcgis.com

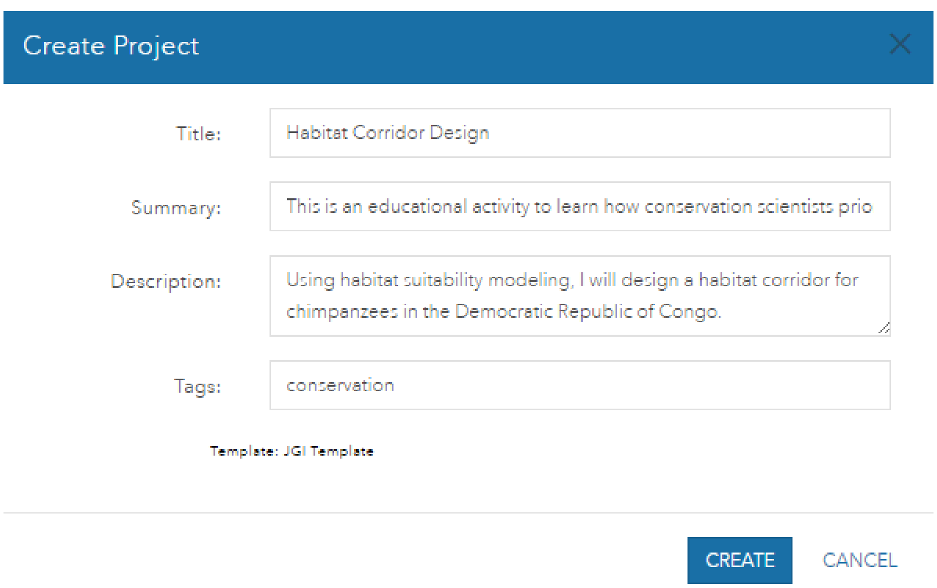
2. Click "CREATE NEW" 

3. Search "JGI" in the search menu and press "SELECT". Make sure the "All" tab on the left is selected



4. A Create Project window will pop up. Fill it out:

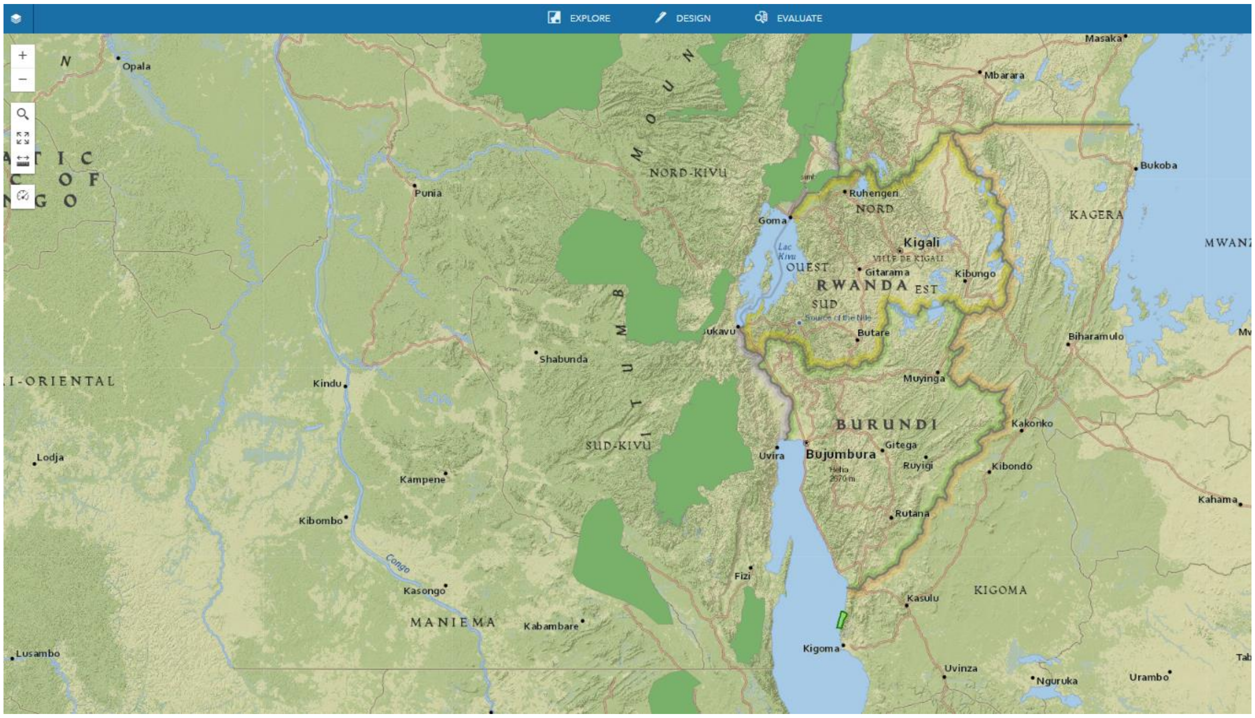
- Title: Habitat Corridor Design
- Summary: This is an educational activity to learn how conservation scientists prioritize optimal conservation locations using geospatial planning tools like GeoPlanner.
- Description: Using habitat suitability modeling, I will design a habitat corridor for chimpanzees in the Democratic Republic of Congo.
- Tags: conservation



Click "CREATE".

5. First explore the map. Using the zoom in and zoom out buttons to get your bearings.

Q1: What countries are in the project extent of this map? (The extent button is)
The Democratic Republic of Congo, Rwanda, Burundi, Tanzania and Uganda.



Q2: Using cardinal directions (north, south, east, west) where is Gombe National Park located in this map extent?
Southeast.

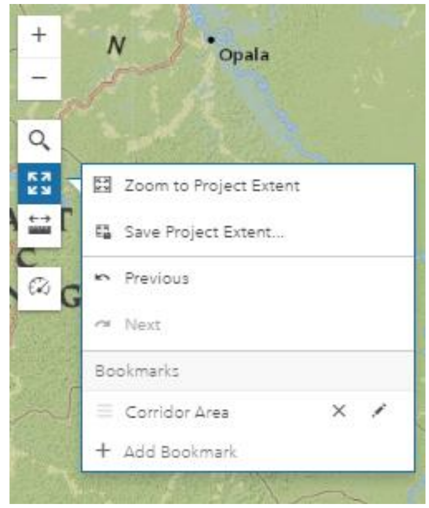
Q3: What are the green polygons and what country are they in?
The green polygons are National Protected Areas in the Democratic Republic of Congo.

6. Then explore the data layers available to you. Click on the Contents button

Q1: There are 5 data layers in this map. What are they?
Gombe National Park, Populated Places, Roads, National Protected Areas and Conservation Suitability.

Q2: What is the basemap set to?
National Geographic.

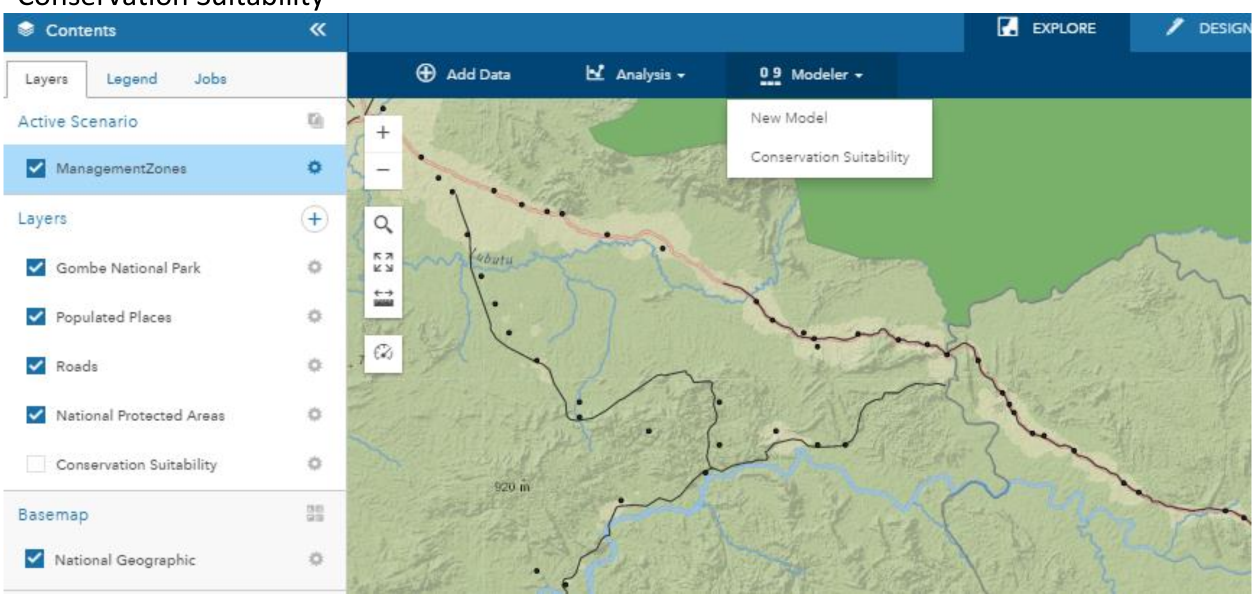
7. Two national parks, Parc National de la Maiko (Maiko National Park) and the Parc National de Kahuzi-Biega (Kahuzi-Biéga National Park) are some of the important core habitat areas critical for gorillas and chimpanzees. Your job is to connect the two national parks by designing a habitat corridor. Note: The pop-ups for the other national protected areas are in French because French is the national language of the Democratic Republic of Congo. Select the Extent button again and choose the “Corridor Area” bookmark. This is your new project extent.



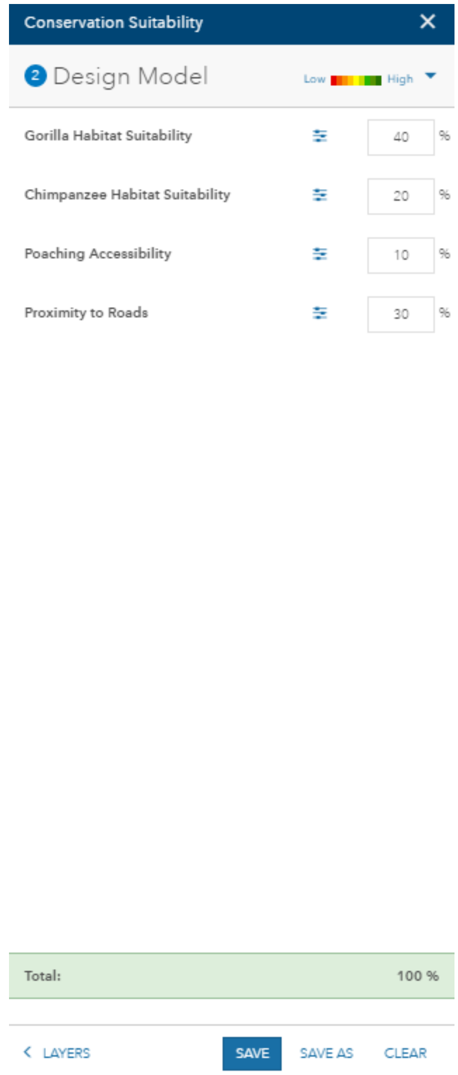
Q1: What is the Area of Maiko National Park? What is the area of Kahuzi-Biéga National Park?

Maiko National Park is 8,910.60 km and
Kahuzi-Biéga National Park is 5,471.92 km.

8. Before designing the habitat corridor, you will perform a weighted habitat suitability analysis to identify the optimal location for your corridor. A suitability model weights locations relative to each other given a set of criteria. Under the “EXPLORE” toolbar, select “09 Modeler” and then the “Conservation Suitability”



9. Next design your model. The current layers that the model is weighing are “Gorilla Habitat suitability”, “Chimpanzee Habitat Suitability”, “Poaching Accessibility” and “Proximity to Roads”. If you select the “LAYERS” button in the bottom left corner, you can add other layers to include in your model (“Deforestation 2009-2013”, “Landcover” and “Slope”) A weighted suitability model assigns different percentages to different factors in a decision. Example 1, out of 100% when determining the value of a potential player, what percent should a sports team manager ascribe to speed, skill, knowledge, compatibility and salary demand? Example 2, in deciding what kind of lightbulb to install in your house, consider the percentage weights you would place on upfront cost, efficiency, brightness, lifespan and environmental impact (must sum to 100%).



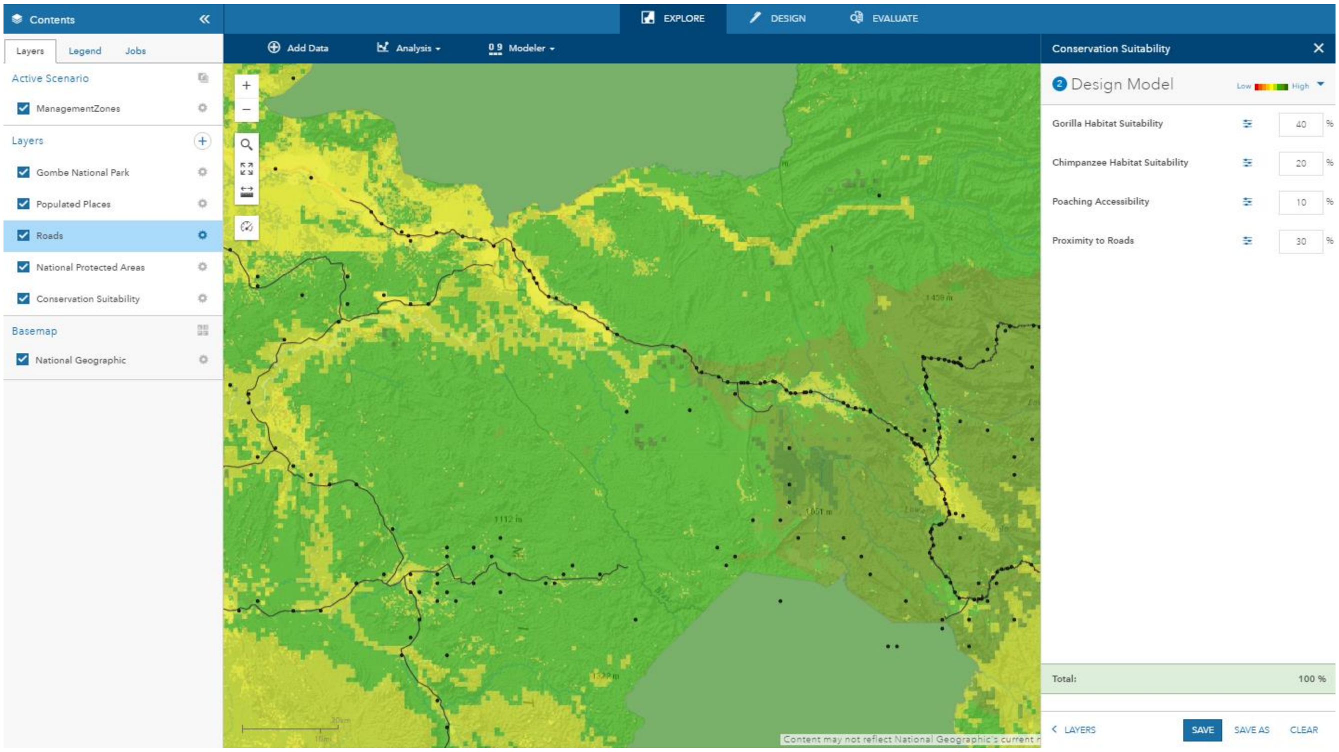
10. Consider which layers are important to include in your model.

Q1: Why did you choose those layers?

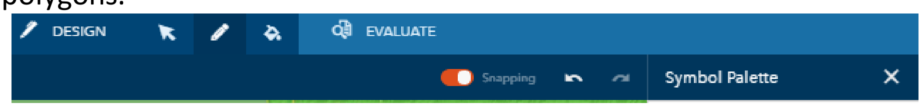
Then change their percentages to choose their weights.

Q2: Why did you choose those weights? (Note the Total must sum to 100%)

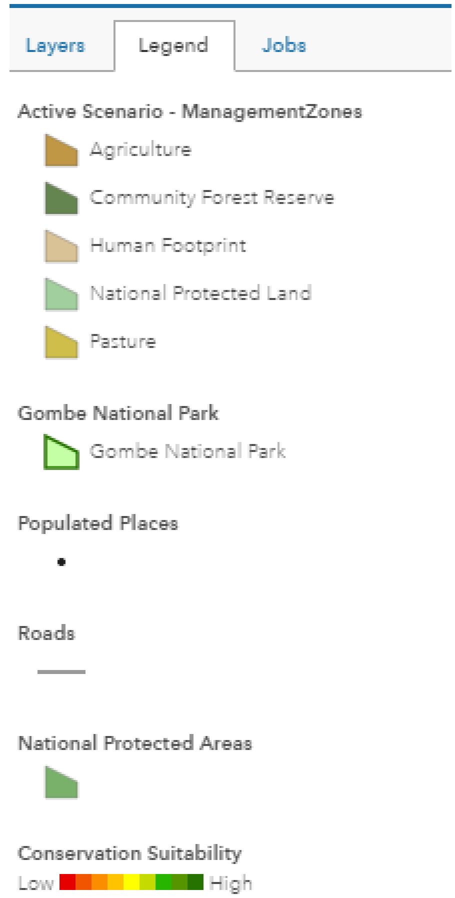
11. Check the Conservation Suitability layer to turn it on. If you used the same weights as in the example, your model will look like this:



12. Now that you've generated the weighted suitability layer, you will design the habitat corridor. Click the "DESIGN" button and then select a land use from the "Symbol Palette". Click on the map to start drawing your polygons.

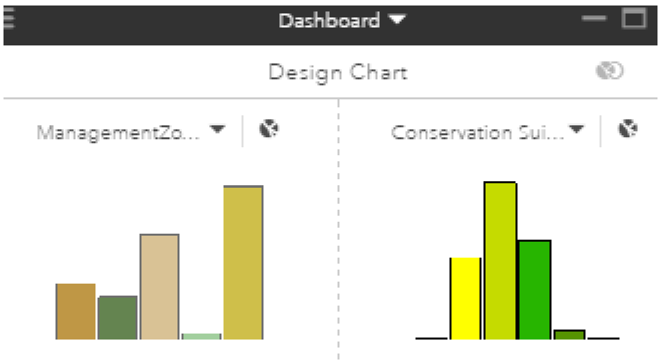


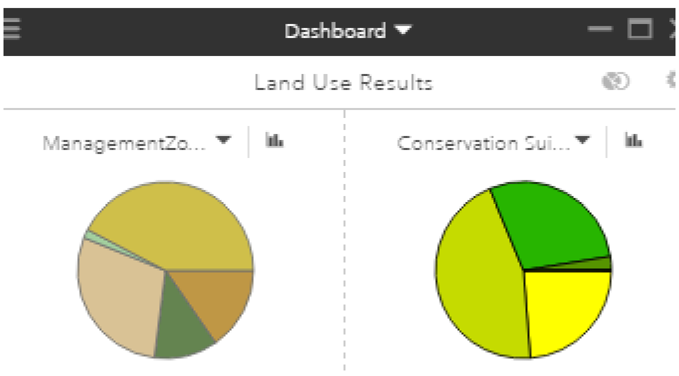
After consulting with chimpanzee and gorilla conservation experts you learn that the animals need a wildlife corridor that is at least 3,000 sq km. Local people have designated 25% of their land for community forest reserves, 25% for agriculture, 25% for pasture and 25% for buildings, roads and infrastructure (represented by Human Footprint). The national government has decided to protect 10% of land in the area.


Layers
Legend
Jobs
Active Scenario - ManagementZones
Agriculture
Community Forest Reserve
Human Footprint
National Protected Land
Pasture
Gombe National Park
Gombe National Park
Populated Places
Roads
National Protected Areas
Conservation Suitability
Low
High


Contents
Layers
Legend
Jobs
Active Scenario
ManagementZones
Layers
Gombe National Park
Populated Places
Roads
National Protected Areas
Conservation Suitability
Basemap
National Geographic
EXPLORE
DESIGN
EVALUATE
DRAW
Snapping
Symbol Palette
ManagementZones
Agriculture
Community Forest Reserve
Human Footprint
National Protected Land
Pasture

13. To evaluate if you met the land use requirements, create graphs to measure the size of your wildlife corridor and show the land use percentages. (Create the graphs by clicking the Dashboard button)





Discussion Question

Q: What are the benefits and limitations of using GIS modeling for conservation planning?

One of the limitations of GIS is that there is a steep learning curve, which makes it difficult to incorporate community members who may not have the training or access to the software. It also requires an internet connection which may be hard to get in remote locations. Data cannot substitute cultural understanding and on the ground experience. A benefit of GIS modeling is that you can design and compare multiple different scenarios before implementing the best choice. As the land use changes on the ground, the map model can be updated.

Citations for Lesson Plan Content

Please note: The Story Map and GeoPlanner activities are for education purposes only. These resources are an introduction to the Jane Goodall Institute's (JGI) community-centered conservation strategy and are not a product of JGI. JGI's land-use planning and community-centered conservation approach is the work of Jane Goodall, Lilian Pintea, Emmanuel Mtiti, the JGI staff, and local communities. As technology evolves, JGI is continually refining its approach. Please visit www.janegoodall.org to learn about the latest methods being used in the field.

Map data and satellite imagery: The Jane Goodall Institute, ESRI, Digital Globe, Wildlife Conservation Society, African Wildlife Federation and World Bank

Photos: the Jane Goodall Institute

Text:

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Chapter 4: Conclusion

There is beauty in youthful idealism. If I knew when I was 11 years old what I know now in terms of the difficulty of actually changing policies and practices to be more equitable and sustainable, I am not sure I would have had the courage to start Project ORANGS. In the face of overwhelming 21st century environmental challenges, we must encourage young peoples' participation and optimism. Conservation is political, messy and multifaceted, meaning that solutions to saving a species are never black and white. We should not shield young people from this reality, rather we should prepare them for it. Environmental educators and mentors can do this in part by teaching interconnected systems thinking and cultural awareness through a spatial, place-based framework.

The purpose of my lesson plan is to give students some insight into how a real-life conservation organization incorporates both local knowledge and science to develop a strategy with local people that works for them and the other animal species who share their environment. Brandt and Smith explain that incorporating students' observations and understanding of their unique place and position in the world to the material they are learning will illuminate why these concepts matter. Because the location for my case study was the Greater Gombe Ecosystem in Tanzania, the challenge is to make this material relevant for students in the United States. I attempted to address this by including questions that helped students notice the similarities and differences in how their community's landscape is developing and to show them how community-centered conservation tools can be applied in their context.

There are three major takeaways I hope students will take from this lesson. First, that there is a reciprocal relationship between humans and their environment. Greenwood and Gruenewald argue that ecological factors inform how human societies function and that humans impact their environment in return. Places are cultural products and there different culturally-derived ways of knowing that can help us understand landscapes better and relate to the people who live in those places. Second, it is useful to visualize global environmental challenges like biodiversity loss at a community scale, acknowledging "the planet is a mosaic of diverse experiences within places" (Greenwood 94). Addressing these challenges then, requires partnering with the people from those places to meet their needs. Third, they can design maps for powerful communication purposes and use geospatial technologies like GeoPlanner and satellite imagery to model different proposals and measure the effectiveness of their plan.

Ultimately, the most exciting aspect of using web-based geospatial technology (the capability for students to interact with and build new map layers from real conservation data) also offers the greatest challenge. While designing the story map and GeoPlanner activities I faced two kinds of problems: interactivity and data. Different web applications have different purposes. For example, with one web application you can show temporal change with an automated timer; with another it is possible to compare two different maps with a sliding bar. I chose the Cascade Story Map template because it can display video, images, web maps and web applications. It cannot embed GeoPlanner or map presentations, meaning I had to continually test what was possible to include into the story map and what was not. By finding various workarounds I was able to create a tool that teachers with little-to-no GIS experience can teach; and that students can click on and navigate the embedded maps through pop ups and map notes. The Story Map Cascade template is in beta version, and I anticipate its functionality will only improve over time.

For the GeoPlanner activity, addressing the interactivity challenge required adapting the tool for the classroom. Simplifying it meant designing a template that defined the drawing choices that students could pick from (forest reserve, agriculture, pasture, national park land and human impact) and including a predetermined conservation suitability service that allowed students to add different layers (proximity to roads, chimpanzee conservation, gorilla conservation, slope) and change the weights. I find this new web tool very exciting because it designs different scenarios, analyzes their effectiveness in one place and the results can be easily shared online. Needless to say, an entire team at ESRI helped me create these tools, and I couldn't have done it without their time, encouragement and expertise.

The second kind of problem I faced was with data. Working with real data from the Jane Goodall Institute came with privacy and use complications. While I utilized the land-use layers for educational purposes, once it is publicly shared online it could be employed for any purpose by anyone. Community data is politically sensitive, and because I am not from any of the villages outside Gombe, I wanted to be respectful of the boundaries that have been defined using community mapping. There was also data like chimpanzee-nest location GPS coordinates that could have been useful in displaying how and if chimpanzees are using the habitat corridor. But because the data would be publicly available online, it could have been used for harmful purposes like poaching. Additionally, the JGI data was in different formats, in various units and other languages, so I had to convert it to a uniform standard. Finding other useful data was fairly straightforward through ESRI's Living Atlas, an online, authoritative source of GIS layers and services. In general, there are credibility and stability problems with using someone else's data besides those hosted by ESRI like the World Ecological Land Units layer. If the owner of the data decides to remove the layer from ArcGIS Online, it will no longer appear in my webmap, which is why I uploaded a vast majority of the data as feature services to ensure accessibility. For these reasons, I assume this is why most GIS lessons use fabricated data but I wanted students to interact with imperfect data, because that is what students will likely use in any real setting.

If I could add another topic to my lesson it would be data use. As more and more spatial data becomes accessible through crowdsourcing and open-data platforms, we will need to teach students digital literacy. This means showing students how to think critically about the authority and integrity of data. As creators of their own data, students have an additional responsibility of considering the implications of sharing it publicly. As contributors to public knowledge, students should be taught to accurately describe their data in the metadata descriptions and to obtain the necessary permissions to use data from other sources. Kerski also stresses that digital fluency includes helping students identify the limitations and capabilities of data including the distortion of map projection, resolution, scale and attribute completeness (191).

Limitations in my lesson plan are that it lacks field data collection and service-learning components. I considered adding a national conservation comparative example and decided on the monarch butterfly because the species' range spans most of the country and would be local to the majority of students. My plan was to design a webmap inquiry exploring the threats facing monarchs (primarily habitat loss for urban development and agricultural pesticide use) and the expected impacts on habitat range due to climate change using the USGS' monarch conservation planning tools. Students would use the filter and buffer tools to locate the optimal locations in their county to plant milkweed (the only food source of the monarch butterfly) by looking at criteria like proximity to highway, proximity to protected area, vegetation type, and pesticide use amount.

Applying what they learned from the GeoPlanner activity, they could design habitat corridor scenarios and contribute to a real conservation project: planting a milkweed corridor along the I-35 corridor that follows a main monarch migration path, for example. Students could visit these locations, collect relevant data like soil type and pH and compare the place's actual characteristics to the modeled version of it. Teachers could also use the lesson as a service learning opportunity by asking students to design a map presentation of their findings with a local government or environmental organization representative. The takeaway is that biodiversity loss is not only an international issue, it is happening in students' communities too and that they have the agency to help prevent it. Ultimately, I decided that this kind of investigation would be very time intensive because it requires teacher's semester-long commitment, making widespread adoption unlikely.

The ultimate success of my lesson plan is dependent on how students and educators interact with it. The next step of my thesis is to pilot the activity in the classroom. Gathering teachers' and students' feedback will help me answer questions like: How much time do the individual mapping inquiry activities take? , How easy to answer are the questions given the directions? , Can students articulate the lesson's objectives in the assessment? And, What are the greatest areas for refinement?. I hope the lesson plan will be useful for teachers who want to provide a real context for an environmental science concepts and that it will encourage students to apply culturally conscious, systems and spatial thinking in their own lives. The discussion of ease of use of different GIS tools and the reasons I chose each of them contribute to the growing literature of GIS' application for secondary education. This thesis was a first take on my vision for environmental education: that students will have access to emerging geospatial technologies that will allow them to investigate the world in new ways, while understanding the critical role that culture and social systems play in shaping our shared landscape through service learning projects of their design. This I believe, will ultimately empower the next generation of empathic, innovative problem-solvers.

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