MAPPING POTENTIAL 2028 SCENARIOS FOR MANG'ULA A, TANZANIA AND MANG'ULA B, TANZANIA AFTER THE KIDATU-IFAKARA ROAD CONSTRUCTION:

Suitability Analysis for Human Settlement, Scenario Building Based on Varying Policy Focus, and Analysis of Capacity for Population Growth

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INTRODUCTION

Infrastructure developments increase economic and social access, with the capacity to reshape adjacent villages in both positive and negative ways; these developments are often pursued in biodiverse, tropical areas that are difficult to access but offer great economic value in raw materials or tourism. The construction of the paved Kidatu-Ifakara road passing by Mang'ula A, Tanzania and Mang'ula B, Tanzania, which is expected to be completed in 2021, will have a profound impact on the movement of people to and facilitation of product transport from these villages; it will better connect them to the markets and resources of larger towns and cities. Lack of reliable road infrastructure, as exists near Mang'ula A and B, contributes significantly to community and conservation challenges by limiting economic diversification and income generation that could reduce dependence on local natural resources. Kilombero District, which contains Mang'ula A and B, has "residential, institutional, commercial, industrial, agricultural, conservational and recreational land uses," the proportions of which are likely to shift in these villages in response to improved infrastructure and resulting economic diversification (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. 50). At the same time, this improved infrastructure will open Udzungwa Mountains National Park to a larger audience of potential tourists and local community residents seeking its resources. Strain on the environment due to increased economic opportunity and migration will likely be seen in Mang'ula A and B.

In order to reap the benefits of increased access to biodiverse areas without suffering irreversible environmental or social consequences, careful planning must be undertaken to mitigate costs. This project's scope is to develop six potential 2028 scenarios for Mang'ula A and B that simulate areas of potential settlement in the villages based on social and economic changes resulting from the Kidatu-Ifakara road. The six future scenarios are as follows:

1. Business as Usual
2. High Environmental Protection
3. Commercial Agriculture Focus
4. Ecotourism
5. Proactive Growth
6. Uncontrolled Growth

Analyses to determine capacity to accommodate population growth and change in areas of land designated with different suitability levels between the Business as Usual scenario (Scenario 1) and other scenarios (Scenarios 2-6) are developed to further interpret the data. The development of potential land use change and settlement suitability scenarios based on different policy focuses are imperative for effective community planning.

BACKGROUND

Infrastructure Improvements as Drivers of Change

Infrastructure projects such as the Trans-Oceanic Highway in Peru, Brazil, and Bolivia provide examples of how communities can be changed by facilitated transportation through road improvements. Even more than the main Trans-Oceanic Highway development, the resulting settlements and connecting roads have increased deforestation rates in the surrounding area as a response to increased land values adjacent to the highway (Delgado 2008, p. 2, 29-30). Road improvements also restructure market connections by drawing rural producers without paved roads to urban markets that are not their nearest market simply because they have paved roads (Perz, Shenkin, Rondon, and Qiu 2012, p. 11). These economic shifts may open new opportunities for economic diversification, which can lead to demographic and land use changes that have far-reaching social and environmental ramifications.

Africa is currently experiencing widespread, rapid implementation of infrastructure projects "driven largely by foreign investments, most notably from China" (Laurance et al. 2017, p. 75-76). The World Bank and other development institutions have focused on southern Tanzanian infrastructure development as a means to increase tourism by facilitating access (The World Bank Group 2015, p. 30). African ecotourism, however, may not benefit from further road development; roads and increased traffic in biodiverse areas threaten the continued existence of elephants and other large mammal populations that draw tourists to the continent (Laurance et al. 2017, p. 76).

Introduction to Mang'ula A and B

The Mang'ula area has high levels of poverty; an estimated 30.8% of residents in Morogoro region ("representative for Kilosa and Kilombero districts") are in "severe poverty" (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. 47). The average household size in the Mang'ula ward is 4.2 (Nyundo, Mtui, and Kissaka 2006, p. 3). In 2012, 3,060 people lived in Mang'ula A and 5,418 people lived in Mang'ula B (Tanzania National Bureau of Statistics 2012).

The T1 trunk road and TAZARA railway (which pass Udzungwa Mountains National Park to the north and south respectively) are the notable existing road infrastructure in this area (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. 54). High vehicle maintenance costs contribute to extensive transport costs that constrain villagers to local markets. Increasing access to larger markets can almost double selling prices for agricultural goods and heavily impact local income (Kikula, Mnzava, and Mung'ong'o 2003, p. 27). Increased income makes alternative, less environmentally harmful energy sources more affordable (Nyundo, Mtui, and Kissaka 2006, p. 54, 55).

Agriculture is the region's primary activity, with "farming, fishing, and pastoralism dominant in Kilombero district" (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. 50, 51; Nyundo, Mtui, and Kissaka 2006, p. 3). Agro-industrial work and micro and small-scale enterprises are also significant employment opportunities which depend on the ecosystem services of Udzungwa Mountains National Park (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. 54; Nyundo, Mtui, and Kissaka 2006, 42).

REGROW and SAGCOT

The Resilient Natural Resource Management for Tourism and Growth (REGROW) is a government-led project that "aims to promote economic development in the SWA [Southern Wildlife Area]; provide legitimate alternatives to illegal exploitation of natural resources, and fund better management of the biodiversity" (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. viii). REGROW's specific goals with respect to infrastructure development are to "improve the Priority PAs [Protected Areas] infrastructure to enhance access and tourist experience" and "strengthen access to improved livelihood activities for selected communities in proximity to the priority Protected Areas," which echo the opportunities created by the Kidatu-Ifakara road (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. viii). The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) has similar goals that align with the Kidatu-Ifakara road project. One of their focuses is transportation, which provides "increased access to farming" and "promote[s] trade, tourism, and foreign investment," especially because it is "the major facilitator of agri-business activities for the SAGCOT Region" (Tizeba 2012).

Population Growth due to Migration in Mang'ula A and B

Infrastructure improvements will likely increase migration to Mang'ula A and B due to greater ease of travel and attractiveness of markets. Settlements around Udzungwa Mountains National Park have already attracted a large number of migrants; a study of 9 villages around the national park yielded that 37.4% of heads of households have migrated to the area (Harrison 2006a, p. 16). Protected areas in general have attractants for migrants such as "foreign aid and integrated conservation and development projects (e.g., schools and clinics), employment (e.g., staff positions and tourism), enhanced ecosystem services (e.g., wood, food, water, and traditional medicine), market access (e.g., road infrastructure), and security (e.g., guards and government staff)" (Wittemyer 2008, p. 123). Social and political conditions, in addition to economic opportunities, drive migration (Hoffman, Fay, and Joppa 2011, p. 3). Seasonal labor opportunities on sugar cane plantations, arable land for farming, and trade potential are especially influential in drawing migrants to the UNMP villages (Kikula, Mnzaca, and Mung'ong'o 2003, p. 7; Nyundo, Mtui, and Kissaka 2006, p. 3). Migrants seeking seasonal labor opportunities are most likely to come from Morogoro or Iringa regions (Kikula, Mnzava, and Mung'ong'o 2003, p. 18). Most migration occurs in "urbanized villages," which Mang'ula A and B could resemble after the road development (Kikula, Mnzava, and Mung'ong'o 2003, p. 7).

Migration to the area introduces new actors who have different desires for the future of the villages. Community cohesion can be a valuable tool for conservation, as cultural norms and customs like religion have historically and presently driven views on conservation (Claus et al. 2010, p. 270-271). Migration into the Udzungwa Mountains area has diverted practice from traditional religions that place a premium on conserving mountain land as the home of the god Bokela (Kikula, Mnzava, and Mung'ong'o 2003, p. 9). This results in "far fewer young people hav[ing] such a spiritual connection with the forests" (Harrison 2006b, p. 48). Anticipating community change over time and representing different viewpoints strengthens policy comprehensiveness and enforcement capability. In this case, creating scenarios and plans to determine how Mang'ula A and B can accommodate greater migration from the Kidatu-Ifakara road is a critical first step.

Conservation and Udzungwa Mountains National Park

Land is a particularly significant resource in Tanzania, yielding important outputs such as food, energy, and income. Tanzania's economy is highly dependent on land-based resources, including for agriculture and tourism (The World Bank 2009, p. 10; Bayliss et al. 2014, p. 75). Resource and land use can be either detrimental to or supportive of conservation. Locals require the ability to use the land to fulfill immediate needs, but their long-term well-being and economic success, and that of others living regionally or globally, also depends on maintaining these resources. Developing states depend on natural capital because they "often possess relatively little physical capital" compared to developed states (Ferraro et al. 2011, p. 20). Natural capital contributes to agricultural production for domestic and foreign use, mining capability, and tourism (The World Bank 2009, p. 10-12). Conserved areas also provide ecosystem services, including "carbon storage, ecotourism, hydrological flows, pollination, health, and NTFPs" (Ferrero et al. 2011, p. 23).

The Eastern Arc Mountains, of which the Udzungwa Mountains are a part, have 96 known endemic vertebrate species and are a critical area for biodiversity conservation (Burgess et al. 2007, p. 209). The Udzungwa and Uvidunda Mountains have "hugely significant water catchment value" and "provid[e] one-third of the nation's electricity through hydroelectric power generation" (Jones 2006, p. 8).

The economic and social changes resulting from the road improvement will influence conservation efforts and require conscientious planning to avoid harmful environmental effects (The World Bank Group 2015, p. 31). More human residency and economic activity will strain the carrying capacity of local natural resources (Harrison 2006a, p. 13). Careful consideration of "targeting high productivity areas for agricultural development" can mitigate these costs (The World Bank Group 2015, p. 31). Creating potential scenarios demonstrating how conserved areas can be effectively preserved despite potential community change and the introduction of new environmental strains in the future is crucial to maintaining these resources long-term.

Agriculture in Mang'ula A and B

Agriculture is an important sector in Mang'ula A and B. In the area of Morogoro and Iringa surrounding Udzungwa Mountains National Park, 70% of the population cultivates (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. 50). Mang'ula Ward has land currently occupied by "Kilombero Sugarcane Company (ILLOVO), Ulanga Rice and Cotton Mills Company, and Kalunga Forest Reserve partly planted with rubber and owned by the General Tyre Company" (Kikula, Mnzava, and Mung'ong'o 2003, p. 16). Within the Kilombero valley area, ILLOVO owns 13,000ha and manages 1,909ha of outgrowers (Kikula, Mnzava, and Mung'ong'o 2003, p. 17, 22). Ulanga Rice and Cotton Company (ULANGACO) has 500ha and 100ha sugarcane plantations in villages neighboring Mang'ula A and B (Kikula, Mnzava, and Mung'ong'o 2003, p. 23). Rice "is the major cereal crop grown in Kilombero Valley both as a food and cash crop" and involves both small and large farms (Kikula, Mzava, and Mung'ong'o 2003, p. 24).

Facilitating transport of agricultural output from Mang'ula A and B will likely only increase the area's attraction for large and smallholder farmers. It is possible that another large company will be interested in owning land in one of the villages. This creates a basis for another potential future scenario in which prime land for agriculture is no longer available for human settlement; this scenario will need to be considered for long-term planning purposes.

Ecotourism for Udzungwa Mountains National Park

Ecotourism is "travel to natural areas that conserves the environment and sustains the well-being of local people" (qtd. in Kiss 2004, 232). Tourism is already a widespread and important sector in Tanzania, capturing 16% of GDP in 2004 (The World Bank 2009, viii). While tourism in general is a great boon to the Tanzanian economy and has benefits for wildlife as well, problems remain with restricted access for locals and relocation of nearby communities. Ecotourism, which has a dual mission of conservation and promotion of community well-being, may be a more sustainable answer that meets the needs of both people and wildlife. Ecotourism provides a better alternative for land use and revenue-building activities that reduces agricultural reliance; it could employ local community members and feed revenue back into the community in exchange for conservation of the land. Tourism itself has often favored a top-down model of decision-making, with control coming from the government or investors. However, community well-being is an aspect of ecotourism, so it should promote participatory processes that involve community input and consent and has helped to spark and support local activism (Honey 2008, 254).

While there are costs that need to be accounted for, ecotourism is worth preparing for and promoting within Udzungwa Mountains National Park and Mang'ula A and B. Tourism in general may be further developed in Mang'ula A and B through improved infrastructure and could reduce reliance on conserved resources (Dalberg Global Development Advisors and Solimar International 2015, p. 81). REGROW reports "improved connectivity and decreased travel time through road improvements and rehabilitation of airstrips" as a key to improving Southern Circuit tourism, which is far outperformed by northern Tanzania tourism (COWI Tanzania Ltd., Eco Tek, and WEGS Consultants 2017, p. x). With conscientious planning, Mang'ula A and B can foster ecotourism development specifically.

Suitability Analysis Method

The suitability analysis method was developed by Ian McHarg, who sought to create an "ecological planning method" that layered various environmental factors to determine what areas are best for development (McHarg 1992, p. v). His book, *Design with Nature*, was a significant contribution to the conservation movement (McHarg 1992, p. iii). Suitability maps are created by compiling relevant GIS layers of different environmental variables which are assigned different values based on their compatibility with construction (lower numbers signifying greater suitability). These layers are converted to raster form and then each raster cell's suitability values are added to those of its counterpart raster cells in the other layers to form a composite map of levels of suitability. This yields a spatial analysis of economic, environmental, and/or social costs of developing in various places. Each variable in the suitability map can be manipulated to simulate various development schemes with different prioritization of environmental variables; these are useful analyses of the effects of different zoning policies.

Mapping Future Scenarios

Mapping future scenarios also has precedent in other research approaches seeking to provide critical information to policy makers planning for the future. For example, three possible future scenarios were designed for the Eastern Arc Mountains "to demonstrate to policy makers in Tanzania the value of ecosystem services and…strengthen support for conservation" (Fisher et al. 2012, p. 88). In Mexico and Costa Rica, the Alternative Futures approach provided scenarios for land use planning below (Steinitz 2005, p. 3).

METHODOLOGY

Suitability Maps and Scenario Building

This project utilizes ArcMap to develop suitability analyses depicting six potential future scenarios for Mang'ula A and B after the construction of the Kidatu-Ifakara road. The various scenarios were created by manipulating eight environmental variables:

- Elevation
- Slope
- Buffers around village roads
- Buffers around the main road (Kidatu-Ifakara road)
- Buffers around existing structures
- Land suitability for agriculture
- Buffers around rivers
- Buffers around Udzungwa Mountains National Park

The future scenarios were chosen to represent expected changes to the villages based on past changes and precedents in other places that experienced similar infrastructure development. They are as follows:

1. **Business as usual:** Continue human settlement within existing patterns of buffers around environmental variables
2. **High environmental protection:** Increase buffers around rivers and Udzungwa Mountains National Park to protect natural resources
3. **Commercial agriculture focus:** Restrict very suitable, suitable, and fairly suitable agriculture land from human settlement to preserve for agricultural usage
4. **Ecotourism:** Prioritize conservation of natural resources, maintain current buffer of development around Udzungwa Mountains National Park to allow guests close access
5. **Proactive Growth:** Maintain or increase buffers around environmental variables
6. **Uncontrolled Growth:** Decrease or eliminate buffers around environmental variables

Exact specifications for each variable under the different scenarios can be seen in Table 1 (p. 7-8). The specifications for the Business as Usual scenario are based on current buffers between structures and the existing environmental variables as well as recommended construction criteria. Specifications for the other scenarios are built on the Business as Usual baseline specifications; they are extensions or contractions of these specifications based on what is assumed to be prioritized in each scenario. The final two scenarios, proactive and uncontrolled growth, show the difference in where settlement will likely occur with and without enforcement of policy, respectively.

Table 1: Scenario Specifications (Level: 1 = very suitable for settlement, 2 = suitable for settlement, 3 = unsuitable for settlement, 4 = very unsuitable for settlement)

Key: Increased buffer; Decreased buffer; Very decreased buffer

SCENARIO	LEVEL	ELEVATION	SLOPE	VILLAGE ROADS	MAIN ROAD (Kidatu-Ifakara Road)	STRUCTURES	AGRICULTURE*	RIVERS	UDZUNGWA MTNS NP
1: Business as Usual	1	309-495	0°-5°	Outside buffered zone	Outside buffered zone	Outside buffered zone	#4 for agriculture	Outside buffered zone	Outside buffered zone
	2	294-309	5°-12°				#3 for agriculture		
	3	276-294	12°-41.975777°				#2 for agriculture		
	4			Road + 3m buffer	Main road + 25m buffer	Structures + 15m buffer	#1 for agriculture	Rivers + 5m buffer	Park area + 150m buffer
2: High environmental protection	1	309-495	0°-5°	Outside buffered zone	Outside buffered zone	Outside buffered zone	#4 for agriculture	Outside buffered zone	Outside buffered zone
	2	294-309	5°-12°				#3 for agriculture		
	3	276-294	12°-41.975777°				#2 for agriculture		
	4			Road + 3m buffer	4 = Main road + 25m buffer	Structures + 10m buffer	#1 for agriculture	Rivers + 10m buffer	Park area + 300m buffer
3: Commercial agriculture focus	1	309-495	0°-5°	Outside buffered zone	1 = All land outside buffered zone	Outside buffered zone	#4 for agriculture	Outside buffered zone	Outside buffered zone
	2	294-309	5°-12°						
	3	276-294	12°-41.975777°						
	4			Road + 3m buffer	4 = Main road + 25m buffer	Structures + 10m buffer	#3, #2, #1 for ag.	Rivers + 5m buffer	Park area + 150m buffer

SCENARIO	LEVEL	ELEVATION	SLOPE	VILLAGE ROADS	MAIN ROAD (Kidatu-Ifakara Road)	STRUCTURES	AGRICULTURE *	RIVERS	UDZUNGWA MTNS NP
4: Ecotourism	1	309-495	0°-5°	Outside buffered zone	1 = All land outside buffered zone	Outside buffered zone	#4 for agriculture	Outside buffered zone	Outside buffered zone
	2	294-309	5°-12°				#3 for agriculture		
	3	276-294	12°-41.975777°				#2 for agriculture		
	4			Road + 3m buffer	4 = Main road + 25m buffer	Structures + 10m buffer	#1 for agriculture	Rivers + 10m buffer	Park area + 150m buffer
5: Proactive growth	1	309-495	0°-5°	Outside buffered zone	1 = All land outside buffered zone	Outside buffered zone	#4 for agriculture	Outside buffered zone	Outside buffered zone
	2	294-309	5°-12°				#3 for agriculture		
	3	276-294	12°-41.975777°				#2 for agriculture		
	4			Road + 6m buffer	4 = Main road + 30m buffer	Structures + 15m buffer	#1 for agriculture	Rivers + 5m buffer	Park area + 150m buffer
6: Uncontrolled growth	1	309-495	0°-10°	Outside buffered zone	1 = All land outside buffered zone	Outside buffered zone	#4 for agriculture	Outside buffered zone	Outside buffered zone
	2	294-309	10°-12°				#3 for agriculture		
	3	276-294	12°-41.975777°				#2 for agriculture		
	4			Road + 2m buffer	4 = Main road + 25m buffer	Structures + 8m buffer	#1 for agriculture	Rivers + 0.5m buffer	Park area + no buffer

*#1 = very suitable or very suitable with some restrictions for agriculture; #2 = suitable for agriculture; #3 = fairly suitable for agriculture; #4 = unsuitable for agriculture

Analysis of Area Suitability for Human Settlement

The analysis of area suitable for human settlement determines the area (in square meters) that is designated with a certain suitability for settlement. The raster cells, designated with suitability levels 7-22 after the suitability analysis raster calculation, were divided into three suitability classes as follows:

Suitability Class	Raster Calculation	Definition
1	7-9	Very Suitable
2	10-12	Suitable
3	13+	Unsuitable

The number of raster cells with raster calculations in each suitability class were determined for each map. Each raster cell is 5 meters by 5 meters, so the number of raster cells was multiplied by 25 m^2 to calculate the area of each suitability class in square meters. These areas were converted to square kilometers. The area of each suitability class was calculated as a percentage of total land area. For each suitability class the percentage change of area between the Business as Usual scenario and the other scenarios was calculated. The formula for percentage change is:

$$\frac{(Area\ of\ scenario\ to\ be\ compared)-(Area\ of\ Business\ as\ Usual\ scenario)}{Area\ of\ Business\ as\ Usual\ scenario}.$$

The number of people who can be accommodated on each suitability level of land given current population density in Mang'ula A and B was also calculated to provide a different metric for representing the amount of land in each suitability class. Current population density for Mang'ula A and B together was calculated by measuring the approximate currently populated area in ArcMap and then dividing the total 2012 population for Mang'ula A and B by the approximate currently populated area. The population accommodation level of each suitability class was calculated by multiplying the current population density for Mang'ula A and B by the area of each suitability class.

Population Projections

Population data for 1978, 1988, 1999, and 2012 for Mang'ula A and B is known. Trend population growth for 2028 was calculated by assuming linear population growth continuing at the same growth level as in past years. The equation for Mang'ula A trend population growth is: Projected Population = 30.287*(Year of Projection)-57317. The equation for Mang'ula B trend population growth is: Projected Population = 110.04*(Year of Projection)-216176. Population was also projected at a higher level, assuming that there is a high influx of migrants after the construction of the Kidatu-Ifakara road makes access much easier and the area more desirable. This higher level assumes that the 2012 population has doubled by 2028 (2012 population is multiplied by 2).

The projected population change from 2012 to 2028 was used to calculate a proportion of projected population that could be accommodated in very suitable or suitable land (the only land suitability classifications that are reasonable for new settlement). The calculation for this proportion is: $\frac{(population\ accommodation\ level\ for\ designated\ suitability\ class)}{(projected\ population\ change\ from\ 2012\ to\ 2028)}$.

Table 2: Mang'ula A and B Population Data

Past and Current Population (Kikula, Mnzava, and Mung'ong'o 2003, p. 8; Tanzania National Bureau of Statistics 2012)

Year	Mang'ula A	Mang'ula B	Total
1978	2,905	2,419	5,324
1988	1,631	1,034	2,665
1999	4,735	4,234	8,969
2012	3,060	5,418	8,478

Projected Population 2028

Trend growth 2028	4,105	6,985	11,090
Population double 2028	6,120	10,836	16,956

Projected Population Change from 2012 to 2028

Trend growth 2028	+1,045	+1,567	+2,612
Population double 2028	+3,060	+5,418	+8,478

Significance of Methodology

This project will elucidate changes that Mang'ula A and B will likely face in the 10 years after the construction of the paved road. These include economic, social, and environmental impacts that can be simulated. Devising various scenarios for prioritization of land use in these villages will indicate the critical effects of policy in mitigating negative consequences of infrastructure development. The population capacity analysis yields information on the ability of different suitability levels of land to accommodate the population growth likely over time and with the addition of the Kidatu-Ifakara road. This data can be used to inform policy makers of likely consequences of uncontrolled development and to help identify priority policy measures that they should act upon now. Similar procedures of scenario-building and population capacity analysis can be adapted for other villages experiencing comparable infrastructure investments or other development projects and may have a great impact on the accuracy and comprehensiveness of village land use and community development planning.
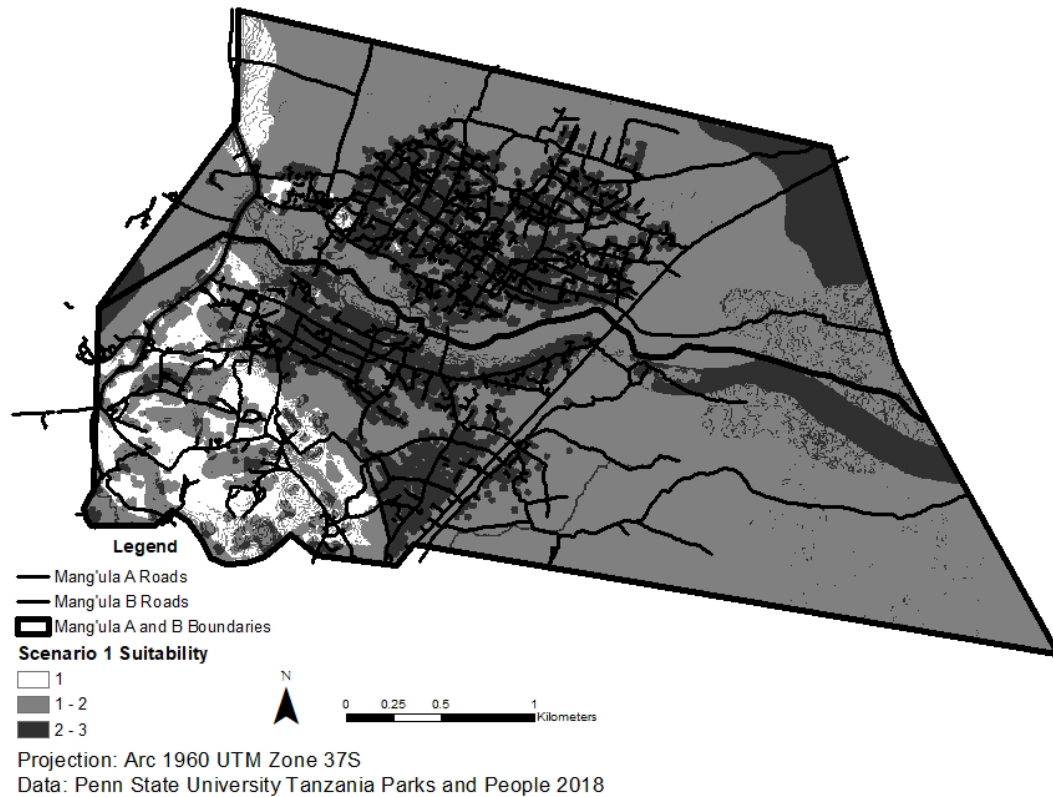
RESULTS

Scenario 1: Business as Usual (BAU)

Scenario 1 indicates the general suitability of land in Mang'ula A and B assuming that the approximate current buffers around features and typical regulations for slope and elevation are maintained. Figure 1 indicates that the main areas of very suitable land occur in the western region of Mang'ula B. The suitable land includes infilling around current development in Mang'ula A and B, as well as expanding into the largely agricultural and old industrial area on the eastern side of the train tracks.

Table 3: Business as Usual Scenario Analysis

Suitability Level	Area (m²)	Percent of Total Village Land (%)	Percent Change of Area from BAU (%)	Population Accommodation (number of people)	Proportion of Increased Projected Population
1	811,050	6.27	0.00	1398	Trend: 0.54 Double: 0.16
2	8,460,750	65.36	0.00	14581	Trend: 5.58 Double: 1.72
3	3,672,300	28.37	0.00	N/A	N/A

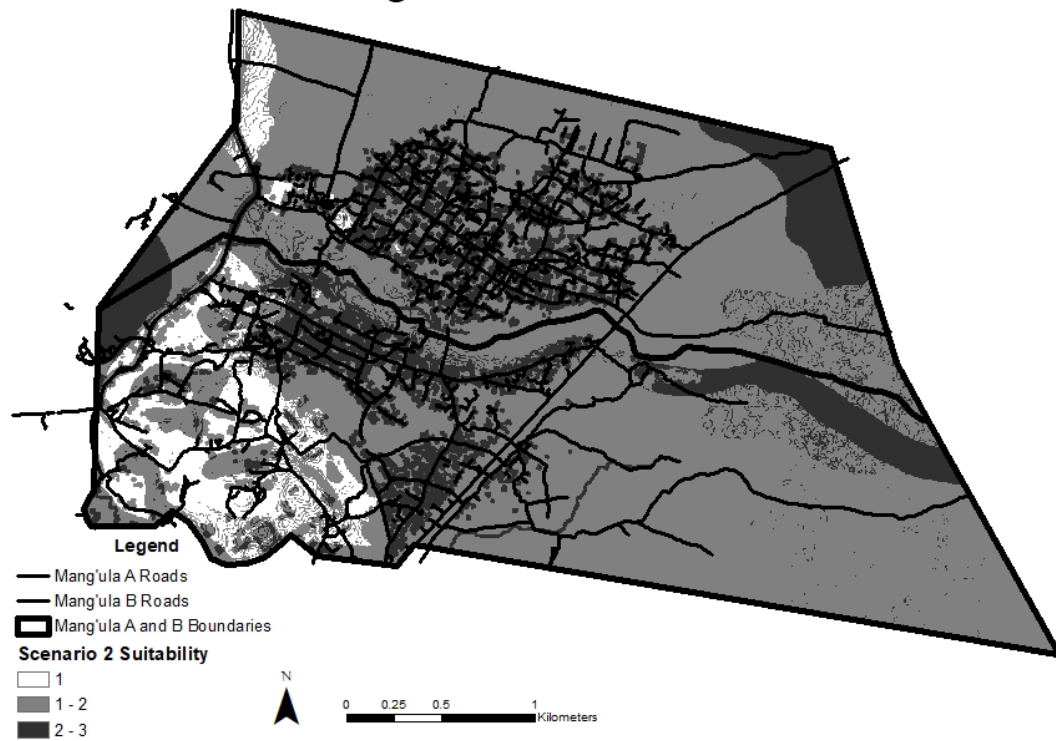**Figure 1: Business as Usual Scenario Suitability Map for Human Settlement**

Scenario 2: High Environmental Protection

Scenario 2 has a greater amount of very suitable and suitable land available than Scenario 1. This highly suitable land is in the same general area as in Scenario 1. The main differences are increased buffers around rivers and an increased buffer around Udzungwa Mountains National Park. Despite these reductions in available land, the total area of very suitable land increases because of the decreased buffers around existing structures (which allows for greater density of infilling). This increased density is also a boon to the environment because it reduces the likelihood that people will settle outside of already populated areas, which reduces land use change. This scenario indicates that natural areas and resources can be preserved without much cost to land availability or quality of life for incoming residents.

Table 4: High Environmental Protection Scenario Analysis

Suitability Level	Area (m²)	Percent of Total Village Land (%)	Percent Change of Area from BAU (%)	Population Accommodation (number of people)	Proportion of Projected Population
1	894,975	6.91	+10.35	1,542	Trend: 0.6 Double: 0.18
2	8,686,075	67.1	+2.66	14,970	Trend: 5.73 Double: 1.77
3	3,363,050	25.98	-8.42	N/A	N/A

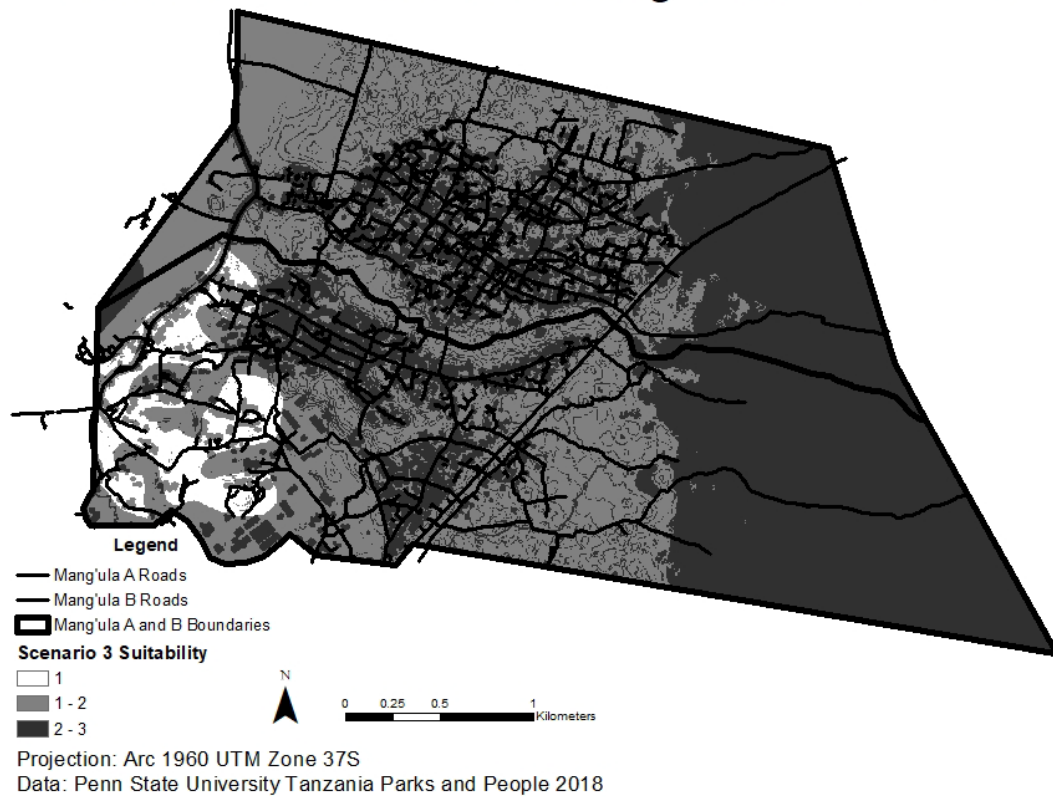**Figure 2: High Environmental Protection Scenario Suitability Map for Human Settlement**

Scenario 3: Commercial Agriculture Focus

Scenario 3 involves the introduction of a new large commercial agriculture company to Mang'ula A and B. Thus, land that is suitable for agriculture is largely restricted from human settlement. This results in a large decrease in available land that is very suitable or suitable from Scenario 1. The only highly suitable land in Scenario 3 is the area in the westernmost corner of Mang'ula B.

Table 5: Commercial Agriculture Focus Scenario Analysis

Suitability Level	Area (m²)	Percent of Total Village Land (%)	Percent Change of Area from BAU (%)	Population Accommodation (number of people)	Proportion of Projected Population
1	544,675	4.21	-32.84	939	Trend: 0.36 Double: 0.11
2	5,059,475	39.09	-40.2	8,720	Trend: 3.34 Double: 1.03
3	7,339,950	56.7	+99.87	N/A	N/A

**Figure 3: Commercial Agriculture Focus Scenario Suitability Map for Human Settlement**

Scenario 4: Ecotourism

Scenario 4 is very similar to Scenario 1 in terms of areas of land for each suitability level; there are not large percentage changes from Scenario 1 to Scenario 4. Ecotourism, with an emphasis on increasing river buffers, maintaining current Udzungwa Mountains National Park buffers, and maintaining existing density for infilling, allows for development with protection of the environment.

Table 6: Ecotourism Scenario Analysis

Suitability Level	Area (m²)	Percent of Total Village Land (%)	Percent Change of Area from BAU (%)	Population Accommodation (number of people)	Proportion of Projected Population
1	902,125	6.97	+11.23	1,555	Trend: 0.6 Double: 0.18
2	8803125	68.01	+4.05	15,171	Trend: 5.81 Double: 1.79
3	3238850	25.02	-11.8	N/A	N/A
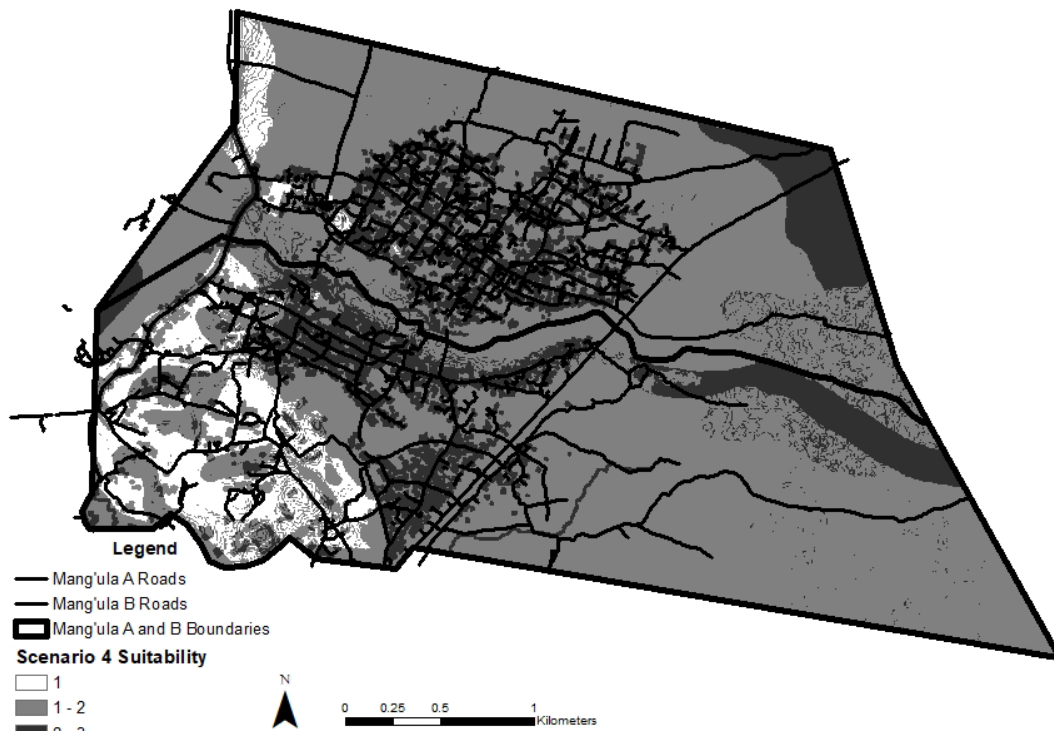
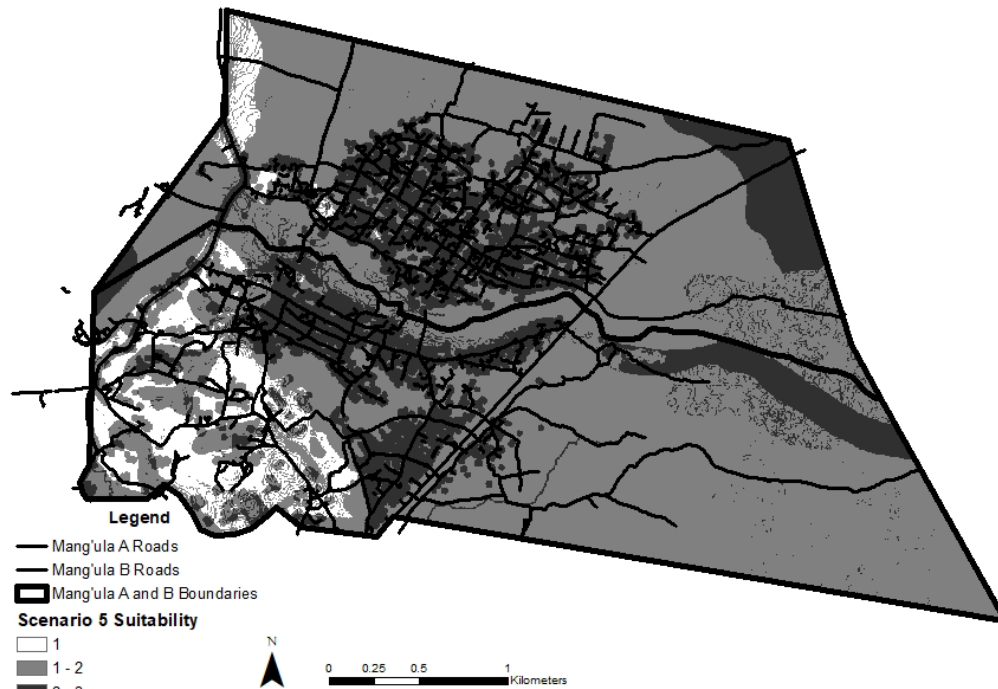**Figure 4: Ecotourism Scenario Suitability Map for Human Settlement**

Scenario 5: Proactive Growth

Scenario 5 is very similar to Scenario 1, with a slight loss of very suitable and suitable land and a gain in unsuitable land. This is because most of the very suitable and suitable land is positioned in areas that will cause infilling of current development; these areas are the ones that were most affected by the larger buffers on roads. These larger buffers may be worth enforcing despite the loss of land because they will reduce dust and noise from cars and trucks that may improve quality of life.

Table 7: Proactive Growth Scenario Analysis

Suitability Level	Area (m^2)	Percent of Total Village Land (%)	Percent Change of Area from BAU (%)	Population Accommodation (number of people)	Proportion of Projected Population
1	759,925	5.87	-6.30	1,310	Trend: 0.5 Double: 0.15
2	8238725	63.65	-2.62	14199	Trend: 5.44 Double: 1.67
3	3945525	30.48	+7.44	N/A	N/A

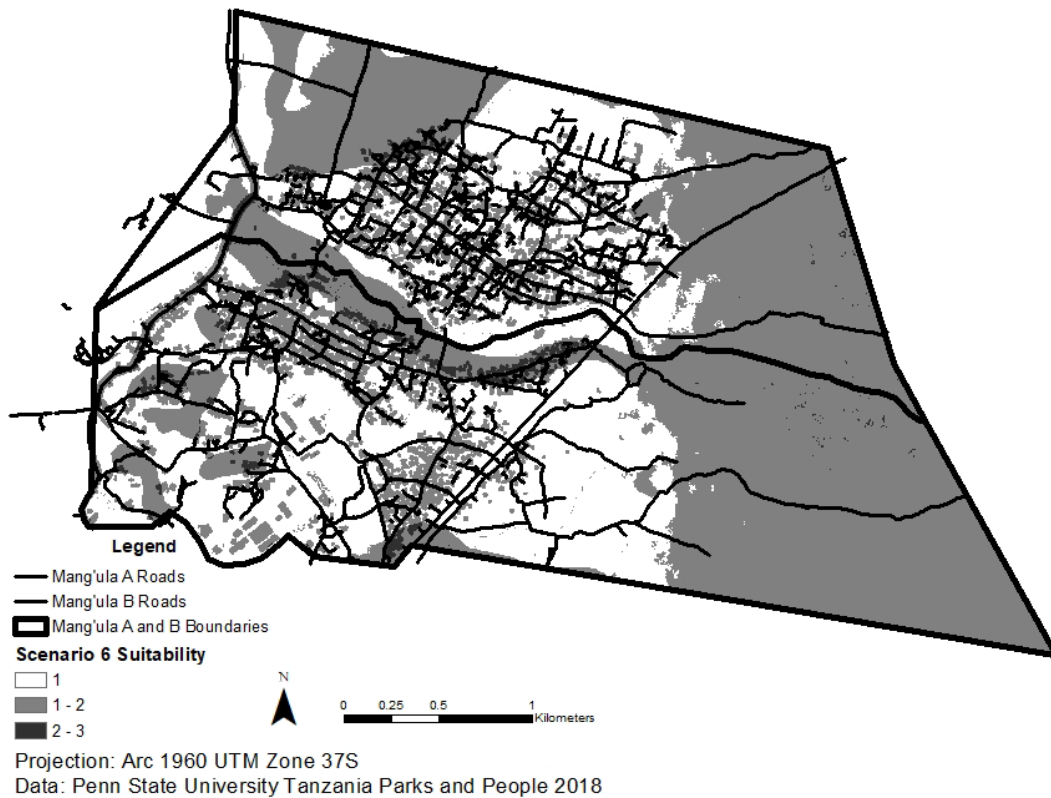**Figure 5: Proactive Growth Scenario Suitability Map for Human Settlement**

Scenario 6: Uncontrolled Growth

Scenario 6 has a large increase in very suitable land from Scenario 1 (see Table 8). This is because Scenario 6 has little to no buffers on all of the features, allowing greater amounts of infilling and development closer to Udzungwa Mountains National Park and the rivers. It is important to note that construction close to roads and structures has negative implications for quality of life and health due to increased dustiness and decreased land per individual. Similarly, construction near rivers and Udzungwa Mountains National Park could increase pollution or natural resource extraction that will have serious environmental consequences locally and regionally.

Table 8: Scenario 6 Analysis

Suitability Level	Area (m²)	Percent of Total Village Land (%)	Percent Change of Area from BAU (%)	Population Accommodation (number of people)	Proportion of Projected Population
1	5,019,725	38.78	+518.92	8,651	Trend: 3.31 Double: 1.02
2	7,490,375	57.87	-11.47	12,909	Trend: 4.94 Double: 1.52
3	434,075	3.35	-88.18	N/A	N/A

Figure 6: Uncontrolled Growth Scenario Suitability Map for Human Settlement

CONCLUSION

The futures of Mang'ula A and B have a wide range of potential settlement patterns and new opportunities resulting from the construction of the paved Kidatu-Ifakara road. The suitability analysis maps and population accommodation analysis indicate that there is enough very suitable and suitable land in each scenario to accommodate the projected increased population of Mang'ula A and B in 2028 at the current population density level. The scenarios demonstrate a Business as Usual projection, as well as five other projections simulating potential futures for human settlement in Mang'ula A and B given different policy focuses. Scenario 6 (Uncontrolled Growth) provides a view of where settlement will likely occur if restrictions are not enforced; this lack of planning is not desirable for quality of life or conservation considerations. Policy makers should consider what factors they want to focus on, whether environmental protection, commercial agriculture, ecotourism, or proactive growth, and can use this analysis to determine the ramifications of each.

For more individuals to be accommodated on very suitable land, the population density will need to be increased for every scenario. Changing density has not been explored in this project, but is a potential method for more sustainable growth on land with higher suitability for human settlement that policy makers should consider. Infilling in areas that are already settled has been demonstrated as a suitable option for human settlement in almost all of the scenarios, so this is a likely starting point for migrant settlement.

Existing land tenure has also not been considered in this project. Land that is suitable or very suitable for settlement may not currently be available for additional settlement because of its ownership restrictions. However, this is another aspect that policy makers will need to consider as changes to the community occur after the introduction of the paved road. It may be most advantageous to land owners and the village as a whole to restructure the land tenure.

Policy makers have many options to prepare for and control the changes to Mang'ula A and B after the construction of the paved Kidatu-Ifakara road. Proactive policy implementation is key to achieve desired results and avoid negative consequences. This project provides a new lens with which to view the potential futures of Mang'ula A and B that gives policy makers a head start on the incoming changes and the ability to more accurately shape the future.

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