# Understanding Njokamoni

## River Study, Spatial Patterns, Issues and Potential for Landscape Design

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# Njokamoni Overview

The Njokamoni River is nestled between the villages of Mang'ula A and Mang'ula B and plays an integral role in both communities. Its headwaters tumble down the slopes of the Udzungwa Mountains, protected by the dense canopy of the Mwanihana Forests and the legal status of Udzungwa Mountains National Park. To the east of the village the river feeds lush fields of sugar cane and rice as it winds through to the Kilombero River.

The Njokamoni runs through primarily agricultural land after leaving the national park. Drinking water for Mang'ula A and B is provided by the river through a system of pipes sourced inside the park. Shambas characterize the primary land use around the river near the mountains, and crops such as maize, paddy, and sugar cane are grown in the section between the two villages. The river is heavily relied upon for irrigation just upstream of the railroad bridge. Human use of the river includes fishing, sand mining, and domestic use, as well as drinking water and irrigation. Prominent vegetation and crops along the river include elephant grass, bamboo, palm trees, maize, rice, and sugar cane. The river is characterized by severe levels of erosion and unstable riverbanks in many places, due in large part to heavy rains . For purposes of this report, the river has been divided into four sections that will be explored in detail.

Local communities depend heavily on natural resources for subsistence, and the health of this river has important impacts on these areas. Other rivers and streams along the eastern edge of the Udzungwa Mountains play similar roles in communities and the environment, and the spatial patterns of the Njokamoni can identified all along the Udzungwa Mountains/Kilombero Valley interface. Therefore, understanding this river and the issues it faces is critical for efforts to develop and implement various types of design efforts in the area. Furthermore, addressing the issues faced by this river will improve the health and well-being of the communities dependent upon it.

## Njokamoni Facts and Figures

- Source in Udzungwa Mountains
- Serves as boundary between Mang'ula A and Mang'ula B
- Length of studied river corridor: 4.36 km
- Approximate total catchment area of studied corridor: 1,300 hectares
- Enters Kilombero River, to Great Ruaha River, to Rufiji River, to Indian Ocean
- 2,000 mm of rainfall annually
- Two rainy seasons: long rains March-May, short rains November-December

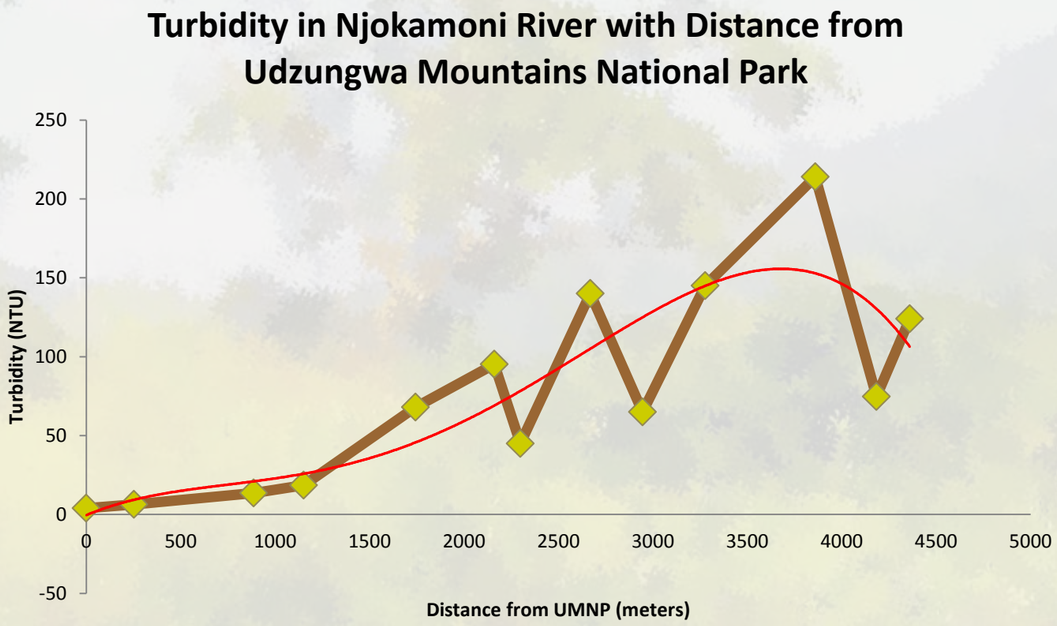

# Njokamoni Water Quality

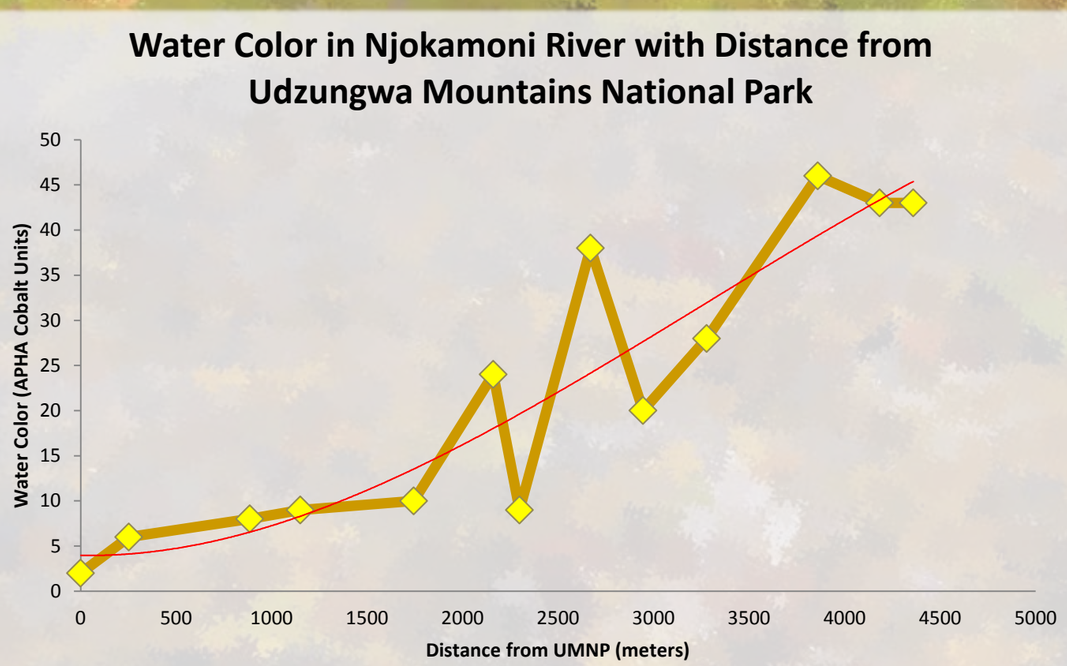
## Water Quality Discussion

**Ecosystem Services:** The turbidity and water color data illustrate and support the idea that the protected Mwanihana Forest ecosystem is providing valuable ecosystem services to the local community. The World Wide Fund for Nature Tanzania Programme has run a project with the goal of conserving “the integrity of the Udzungwa Mountains Catchment” for the purpose of ensuring “reduced pressure and improved utilization of forests, water and land resources” on the eastern side of Udzungwa Mountains National Park (Jones, 2006). This effort directly relates to the quality of the Njokamoni, and there has been much interest in this area to protect ecosystems not only to preserve biodiversity, but also the services to humans that these natural areas provide. The services provided by forests include hydrological services such as the prevention of soil erosion, regulation of water flows and water purification (Ferraro et al, 2012). Forests also have positive impacts on availability of water for irrigation, prevention of sedimentation in river beds, production of drinkable water, and availability of water for domestic use (Ferraro et al, 2012). However, the economic benefits from these services are dependent on the spatial relationship to human activities such as farming activity and downstream demand for clean drinking water (Ferraro et al, 2012).

**Health:** Of these ecosystem services, drinking water has the largest implication for human health. Data collected in villages just north of Udzungwa Mountains National Park show that residents rely primarily on rivers, springs and wells for drinking water, and that the biggest problem associated with water, according to villagers, is safety (Jones, 2006). It is important to note that the watersheds around these villages are characterized by heavy deforestation. Due to a lack of clean water for sanitation, diarrhea rates tend to increase in areas where deforestation has resulted in low stream flow (Pattanyak and Wendland, 2007). Diarrheal diseases are one of the leading causes of death among children in Africa (WHO, 2010) and providing clean drinking water to populations is of paramount concern. Diarrheal diseases can be caused by bacteria, viruses, and parasites (Skolnik, 2008). Forest is effective in purifying water through processes such as filtration, which improves water quality, and correlations between improved water sources and decreased diarrheal related deaths can be found (Gorenflo, 2012). For places where purifying water is beyond economic means, conservation of natural processes can benefit local health (Gorenflo, 2012). Water usage in Mang’ula  benefits from application of these principles, as demonstrated by the high water quality near at Test Site 1, near the Udzungwa Mountains.

# Njokamoni Water Quality




## Water Quality Data

Measurements: According to the website of the Environmental Protection Agency of the United States of America (EPA), "Turbidity is a measure of water clarity and how much the material suspended in water decreases the passage of light through the water." Suspended materials affecting levels of turbidity include soil particles, algae, plankton, microbes, and other substances. Sources of high turbidity levels include soil erosion through run off, waste discharge, and eroding stream banks. Turbidity is a useful indicator of the effects on runoff from agricultural practices (EPA). Turbidity is also a useful indicator of general water quality. Particles in turbid water absorb heat, thereby raising the temperature of the water, which in turn decreases the water's capacity for dissolved oxygen. Therefore, higher turbidity is normally unsuitable for healthy fish populations, and due to less light passing through the water, capacity for photosynthesis also declines. In this project, turbidity is measured in nephelometric turbidity units (NTU's). The EPA's website says that typical clear mountain streams have a turbidity level of around 1 NTU and large rivers during dry-weather have turbidity measured near 10 NTU, although that number will jump into the hundreds during runoff events. Measurements of water color are taken in American Public Health Association (APHA) cobalt units. APHA is a single number yellowness index (retrieved from www.hunterlab.com). Color is used as an indicator of purity and often reflects organic matter in water .

Methods: Data collection was made on June 6, 2013 in a walkthrough of the entire stream corridor of interest. No significant rainfall had occurred over the week prior to the walkthrough. Observations were made of physical geography, adjoining spatial patterns and human activity. Measurements of turbidity and water color were taken at thirteen different test sites along the studied length of the river.

# Issues affecting Water Quality

## 1. Riverbank Erosion

- the most serious immediate threat to the Njokamoni, it causes unstable river banks, loss of crop land and sedimentation

## 2. Agricultural Runoff

- heavy rains in the wet season combined with intensive land use causes significant runoff events and sedimentation

## 3. Village Waste

- debris, trash, and human/animal waste entering the river from house compounds in the village affects water quality

## 4. Irrigation

- high-volume withdrawals of water and disturbance of muddy river bottom through farming contribute to poor river quality

## 5. Fishing

- fishing is intensive in some sections of the river, and activities such as access and dams affect water quality

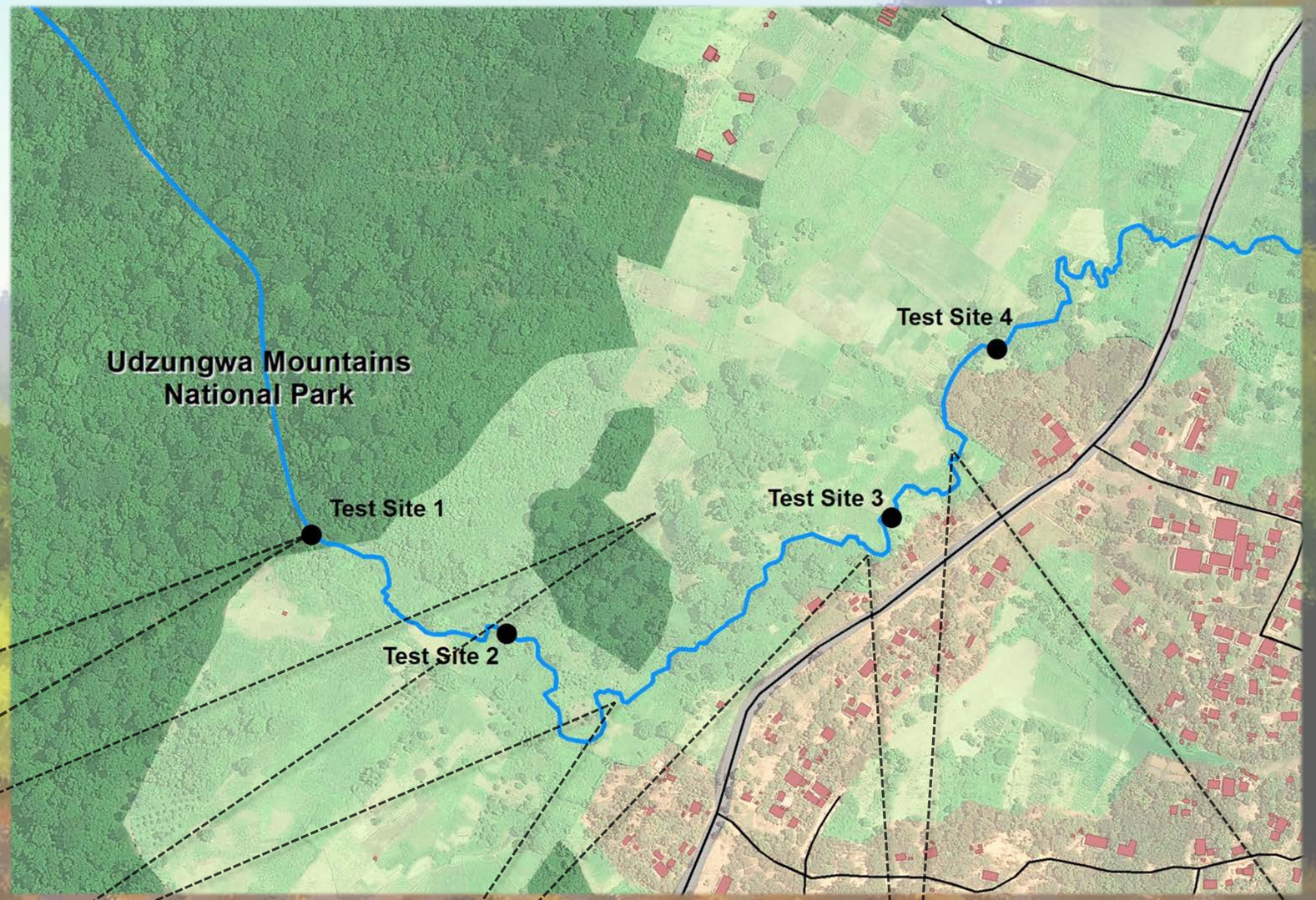
## 6. Sand Extraction

- although important as a building material, sand extraction acts as catalyst for erosion processes

# Section One

## (Test Site 1 to Test Site 4)

This section of river is characterized by the highest quality water, a result of recently exiting the forest. Within the park boundary is the source of the drinking water for most of the village, which is carried in pipes to a system of standpipes. Measurements of turbidity and water color alone do not suggest this water is unsafe for drinking, although it may be. Land use in this area consists primarily of shambas and uncultivated land, although the river does move close to residential areas at some points. Human-wildlife conflict is prevalent here, based on a high number of observed elephant footprints and trails, as well as comments by residents. Some fish traps are noticeable and small minnows can be seen swimming in the shallows. The river bed transitions from primarily gravel to primarily silt within this section, an indication of agricultural runoff. Most of the stream banks have dense vegetation, primarily elephant grass, and the banks appear stable, although some areas closer to the main road show significant erosion. At these areas of erosion effort has been made to reestablish vegetation through planting elephant grasses. The high measurement of turbidity at test site 4 shows the rapidly degrading water quality.




River leaving Udzungwa over boulders

Piped river water used for irrigation

Small dam on river for fishing and irrigation

Debris from residential area washing into river

Elephant grass plantings on eroded river bank

# Section One

## (Test Site 1 to Test Site 4)








**Test Site 1**

- Large boulders up to 0.5 meters diameter in riverbed
- River rapidly losing elevation
- Gravel streambed
- Some deep pools, some shallow channel
- Thick vegetation, large trees
- Farmed land 50 meters from river
- Water appears clean and cool

**Test Site 2**

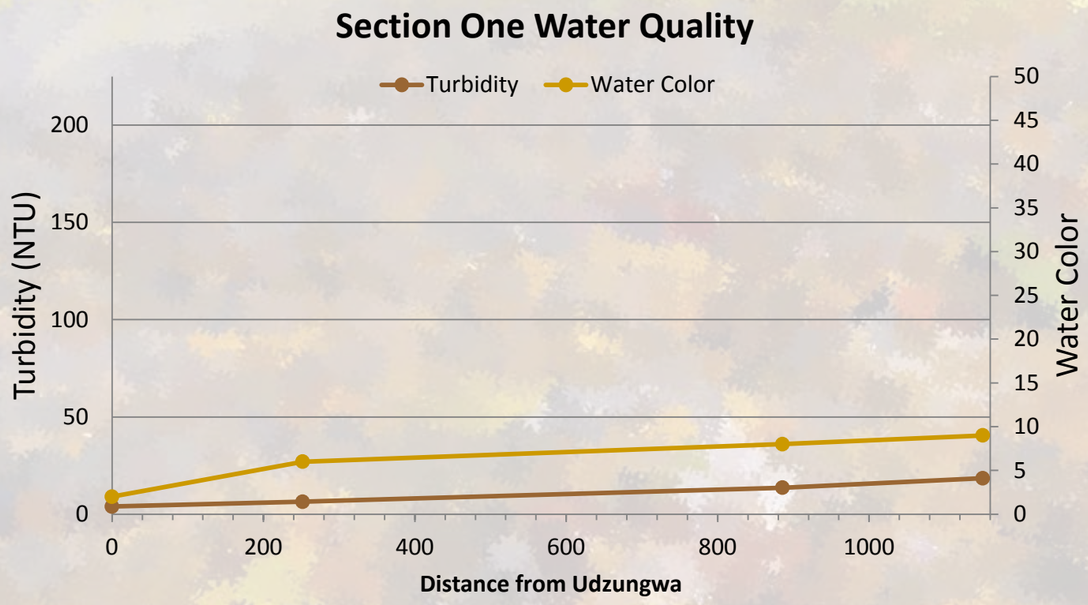
- Gravel riverbed
- Tall grasses and coconut trees
- Slight meanders
- River banks have gradual, gravel slopes
- Elephant tracks and trails common nearby

**Test Site 3**

- Agricultural/residential area
- Pumpkin and spinach planted close to river
- Tall, eroded banks (1.5 meters approx.)
- Deeper channel (0.3 meters approx.)
- First signs of waste in river
- Shorter grasses, ferns, mufufu

**Test Site 4**

- Noticeable change in water appearance
- More sediment, especially on riverbed
- No gravel
- Deeper, slower water
- River banks 1 meter tall on average
- Attempts to plant mufufu in areas of heavy erosion near fields
- Agricultural/residential area




## Issues

### Erosion:

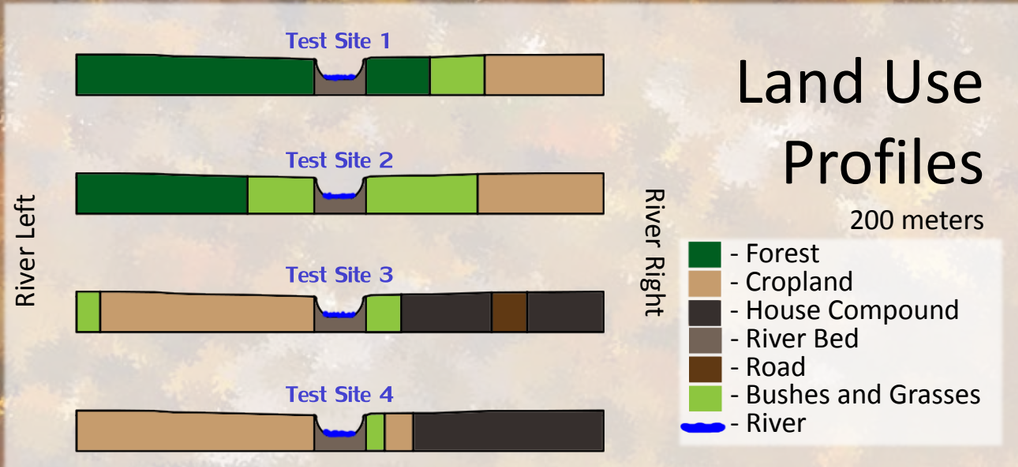
Perhaps the largest issue facing the Njokamoni is erosion. Cultivated land is under threat of being lost in some places due to this process. Un-vegetated riverbanks and riverbeds show signs of the most severe erosion. Turbidity tests along this section suggest the problem of erosion begins in earnest between test sties three and four and observations of river features support this. Efforts to address the issue include small sections of mufufu plantings and requiring all cultivation to be set back five feet from surface water.

### Water Quality:

The water quality inside Udzungwa is high, but it declines once leaving the forested area, especially when it approaches house compounds at test site three. Upstream of test site one is the source of the majority of drinking water for Mang'ula A and B, and protecting this resource is critical to the health of the villages. Within section one it is likely that the water quality degrades from safe for human consumption to unsafe.

### Human-Wildlife Conflict:

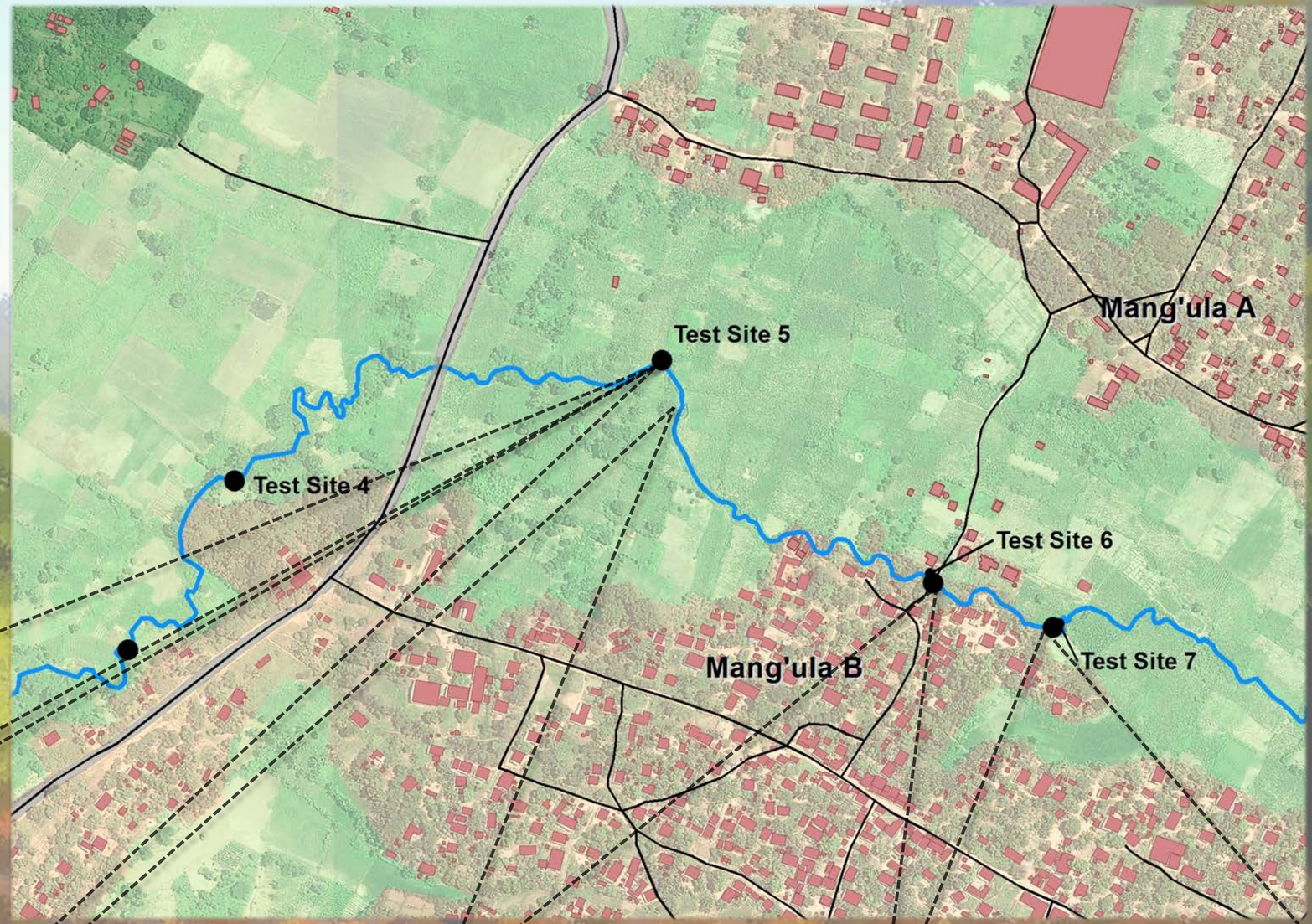
The proximity of this section of river to the protected forest causes high incidence of human-elephant conflict.



# Section Two

## (Test Site 4 to Test Site 7)

This section of river has high levels of human activity and the most extreme cases of erosion . Furthermore, the water quality degrades from good to poor in this area, which is largely a result of human activity and erosion. Design concepts explored by this project will be focused in this section of river, with the hope that improvements here increase the total percentage of good quality water from Udzungwa to the railroad. These efforts will expand the habitat of any sensitive aquatic species located just upstream of this section. Furthermore, the high levels of human influence and extreme erosion make this section the most appropriate area of the river to focus rehabilitation efforts. The river here is characterized by tall banks sometimes exceeding two meters high, meanders with extreme erosion on outside bends and deposition on insides, silt-filled riverbeds and debris cluttering some areas of the river. No noticeable attempt has been made to stabilize riverbanks in this area. Land use is primarily agricultural around the river, with maize being the most common crop. The section between test site six and test site seven is significant because it is directly adjacent to Mang'ula B residential area and its stream banks have benefitted from being stabilized by large trees used for shade. However, the stream banks are tall, showing the riverbed has suffered heavy scouring.




Severe erosion on outside bend of river

Stagnant water along edge of river

River used for washing clothing and dishes

Bridge in Mang'ula B

Stream channel exiting Mang'ula B

# Section Two
## (Test Site 4 to Test Site 7)





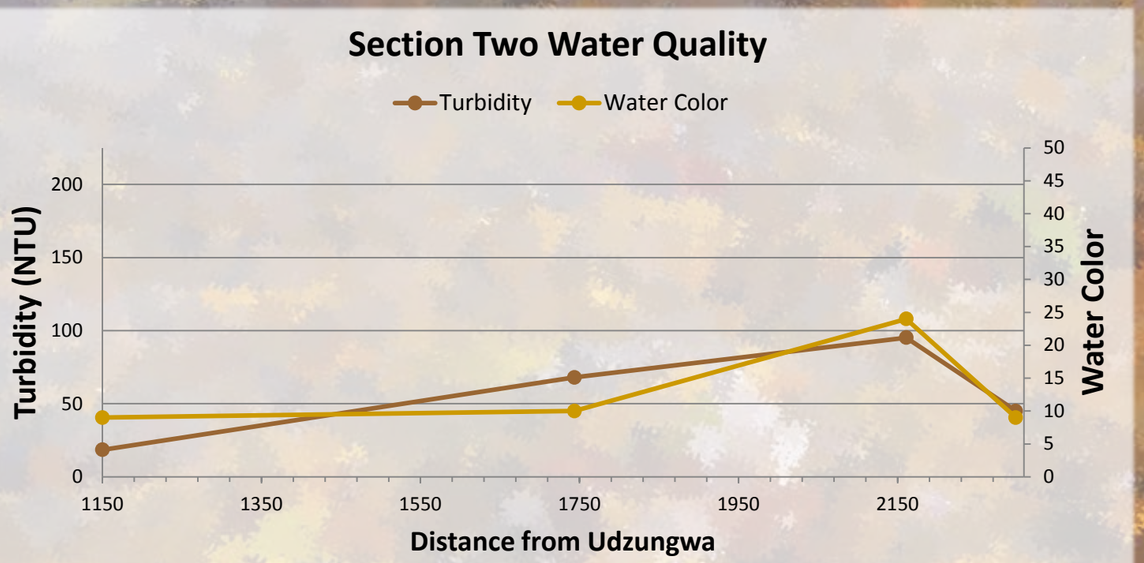


**Test Site 4**
- Noticeable change in water appearance
- More sediment, especially on riverbed
- No gravel
- Deeper, slower water
- River banks approx. 1 meter tall
- Attempts to plant mufufu in areas of heavy erosion near fields
- Agricultural/residential area

**Test Site 5**
- Significant increase in human activity
- Extreme erosion on banks
- Some areas used for sand extraction
- Agricultural area, maize is dominant crop
- Soil primarily silt sand loam, also clay and sand deposits
- Few trees in area
- Meanders (3 meter radius approx.)

**Test Site 6**
- First Bridge in Mang'ula B
- Narrow, straight channel
- Shade trees near houses
- Riverbanks tall (2 meters approx.) and characterized by tree roots
- Heavy human activity
- Animal pens, houses nearby
- Short grasses

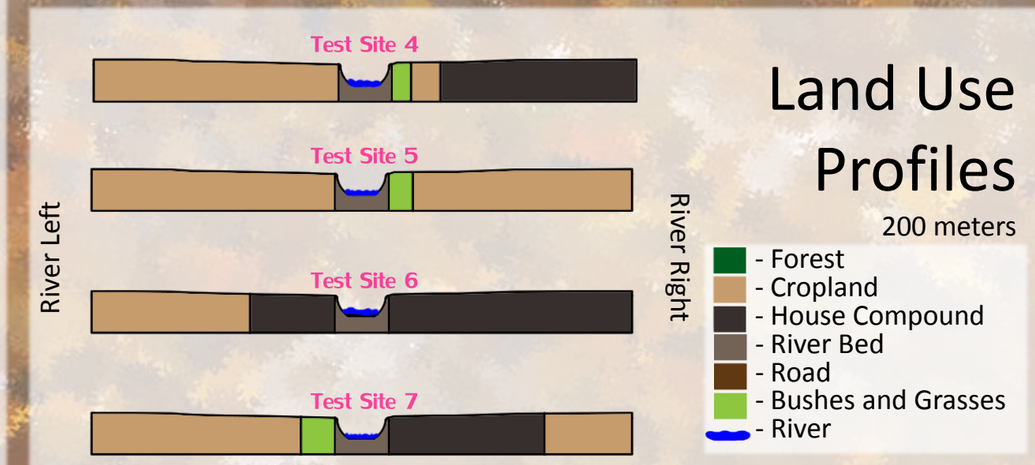
**Test Site 7**
- River leaves long, straight, shaded section in Mang'ula B
- Riverbed contains heavy silt deposits
- Riverbanks approx. 1 meter tall
- River current fast and smooth, no riffles
- River enters maize fields




## Issues

### Erosion:
The erosion in this section of river is more severe than anywhere else, with the most extreme cases among the meanders around test site five. No effort has been made to control erosion in these areas. Riverbank degradation here has implications for sections downstream and contributes to the high levels of turbidity and silt found along the remainder of the river. Human activity appears to accelerate riverbank erosion, as in the area used for washing after test site five. This is due to foot paths providing a catalyst for bank erosion. Sand extraction also provides a catalyst for water to erode and undercut river banks. Scouring and sediment transport also occurs on the river bed, such as in the section between test site six and seven where the current moves quickly.

### Waste from Village:
Debris, trash, and human/animal waste entering the river from house compounds in the village are also cause for concern. These pollutants may have serious implications for the safety of water downstream. House compounds are directly adjacent to the river in some areas.

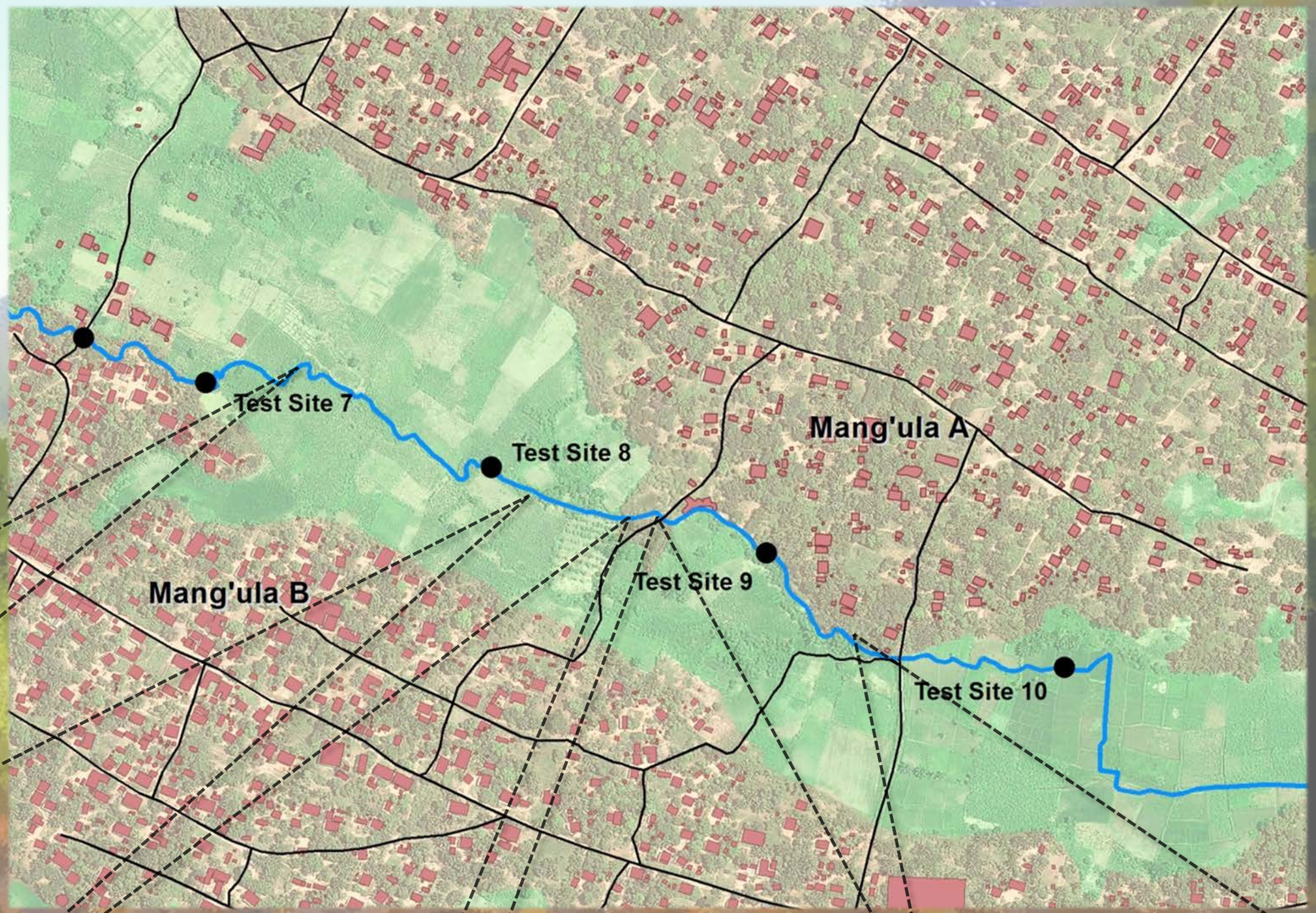



## Land Use Profiles

# Section Three

## (Test Site 7 to Test Site 10)

The land use around this section is entirely agricultural until reaching the edge of Mang'ula A. Maize and banana are the primary crops. Several fish traps occur along this stretch of river, and fishing with nets or rod and tackle is popular closer to Mang'ula A. Small catfish approximately eight centimeters long were being caught during the time of observation, although larger fish closer to a half meter in length are caught in the fish traps. The channel here is deep and narrow with a slow current. Tests of turbidity and color show high levels of both. Erosion in this area is not significant as the current is slow and the banks are thickly covered in tall grasses, bushes and bamboo. However, the channel does widen at meanders and some erosion on the outside of bends and deposition on the inside occurs. Sand extraction is popular in these locations. However, human activity is scarce until approaching Mang'ula B. Test site ten is the last location of an identifiable channel before the entire river is redirected into irrigation.




Channel widening through river bend near maize field

Dam and fish trap

Fishing with net

Crossing point on path between Mang'ula A and Mang'ula B

Deep and slow section of river popular for fishing

# Section Three
## (Test Site 7 to Test Site 10)

**Test Site 7**
- River leaves long, straight, shaded section in Mang'ula B
- Riverbed contains heavy silt deposits
- Riverbanks approx. 1 meter tall
- River current fast and smooth, no riffles
- River enters maize fields

**Test Site 8**
- Agricultural area, primarily maize and banana
- Thick silt layer on river bottom
- Narrow channel, approx. 0.75 meters deep
- Thick mufufu on both sides of river, covering channel in places
- Slow current
- Some open areas at meanders with eroded banks on outside and sediment deposits on inside

**Test Site 9**
- Borders Mang'ula A residential area
- Agricultural fields on river right
- Heavy fishing activity for small minnows and larger fish
- Channel wide (approx. 2.5 meters) and deep (approx. 0.5 meters) with silt bottom
- Slow current
- Series of fish dams, some operational
- Bamboo, grasses, palm trees
- Piles of sand from sand extraction frequent on riverbanks
- No large sediment particles in water

**Test Site 10**
- Last remnants of river channel before full irrigation
- River spreads out into rice fields
- Small currents between fields
- Fish caught between test sites 9 and 10 include catfish ranging in size from approx. 5 cm to 50 cm
- Ground in area is wet and muddy

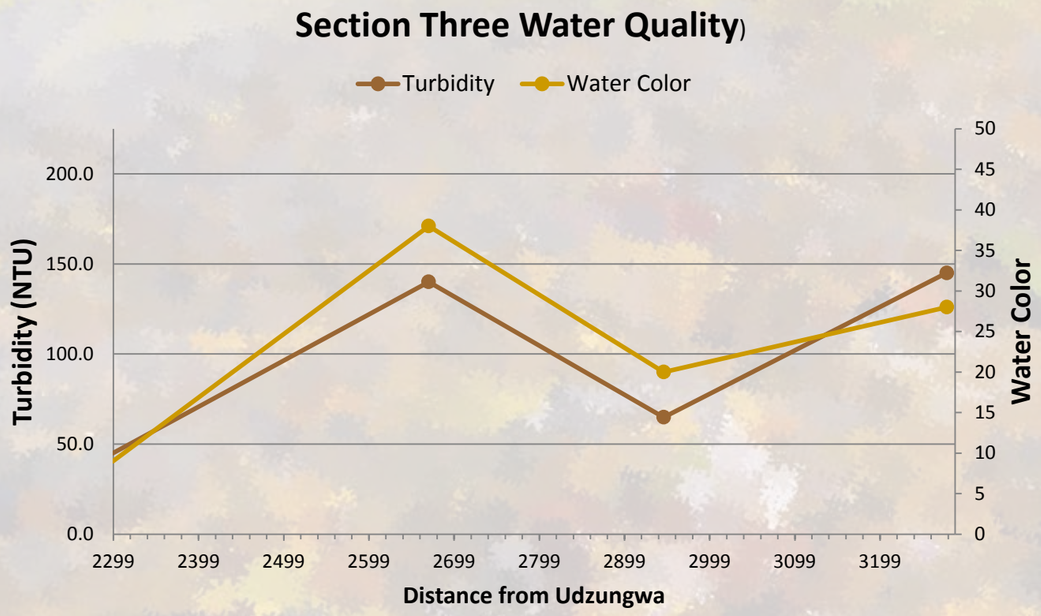
## Issues

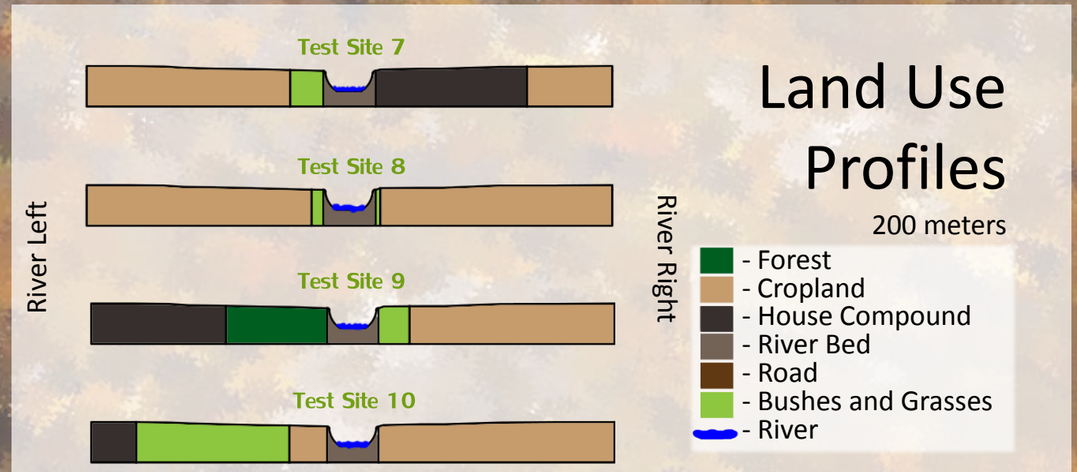
### Agricultural runoff:
This study of the Njokamoni was conducted during a dry period. Therefore, the effect of storm water and runoff along the entire length of the Njokamoni were not present in observations or measurements. However, it is presumed that the heavy rains in the wet season combined with intensive land use cause significant runoff events. Certain patterns of land use and agricultural practices may make the river more susceptible to runoff. It is likely that the majority of sediment in this section of river entered the river through runoff.

### Riverbank erosion:
Although less severe here, erosion does occur along the outsides of river bends and at the crossing between test sites eight and nine.

### Pressures from fishing:
The primary human activity directly impacting the river along this section was fishing. How this pattern of heavy fishing affects the river is unknown, but understanding these implications and taking steps towards increasing yields of fish would benefit village residents.



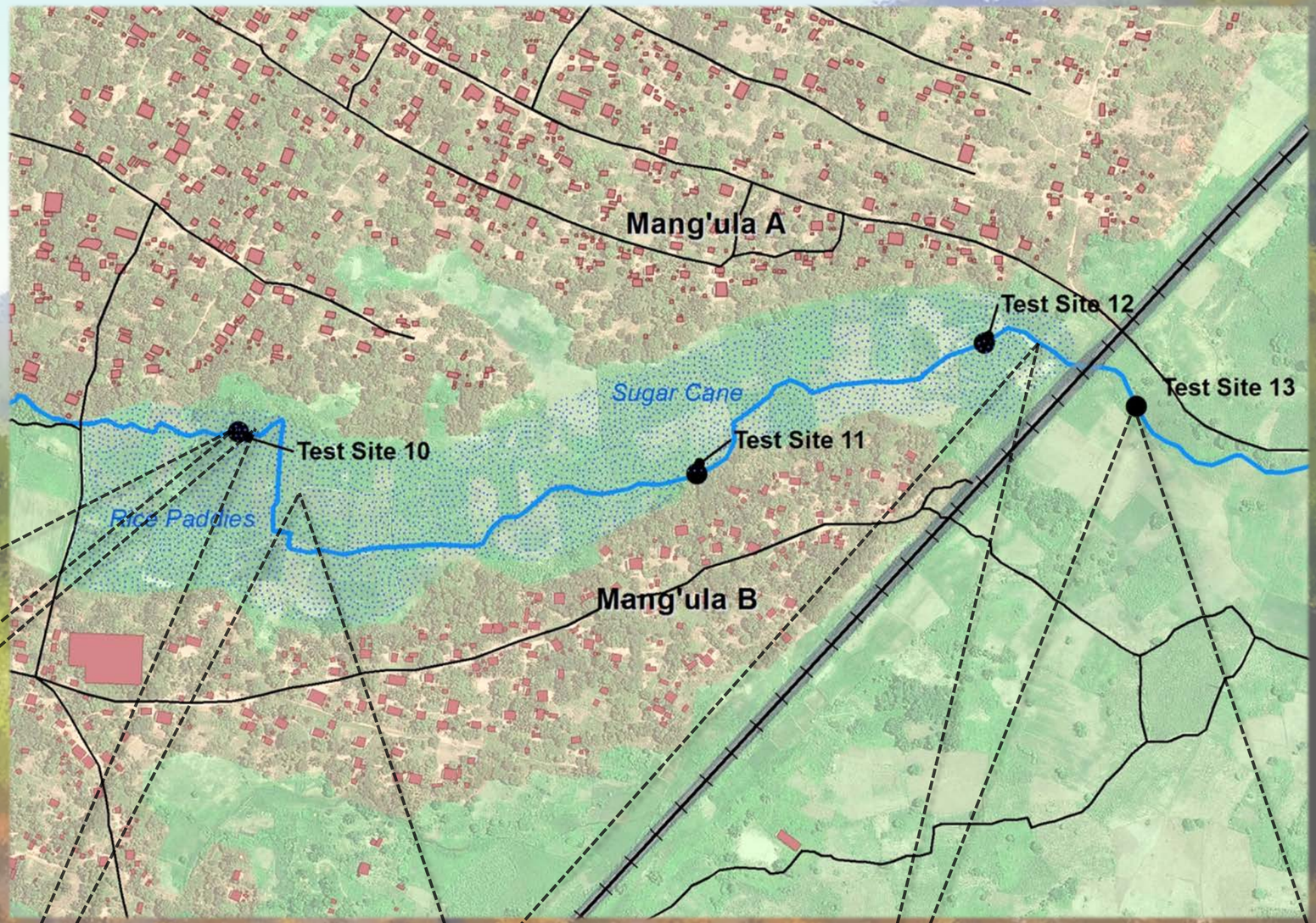


# Section Four

## (Test Site 10 to Test Site 13)

The final section of the river ranges from where the channel disappears into irrigation to where the river reforms with significantly less volume after passing under the railroad. The creek initially flows into rice paddies with deep mud and small currents between plots. In some sections channels reform briefly before spreading out again. The fields range between the developed areas of Mang'ula A and Mang'ula B. No paths cross this section of river until the railroad, although people are frequently working in the fields. Turbidity in this area is very high. The primary crop changes from rice, upstream, to sugarcane, closer to the railroad. Test sites eleven and twelve are both located at irrigation channels within the irrigated land. Because of the elevated railroad grade, all water must drain from this area under the railroad bridge near test site thirteen, which is the only outlet, forcing the river to reform. The trend of irrigation appears to continue beyond the railroad. Conserving water along the entire Njokamoni would benefit the capacity for irrigation along the river corridor in areas similar to this section.




Last remnants of river channel before full irrigation

River being redirected into fields for irrigation

Rice paddies

Channel reforms after sugar cane fields

Final test site after railroad bridge

# Section Four

## (Test Site 10 to Test Site 13)




**Test Site 10**
- Last remnants of River channel before full irrigation
- River spreads out into rice fields
- Small currents between fields
- Ground in area is wet and muddy

**Test Site 11**
- Channel re-identified along border of Mang'ula B residential area
- River proceeds from rice fields to sugar cane fields
- Test site is adjacent to sugar cane fields
- Deep mud at bottom of deep channel
- Very slow current
- Obvious loss in volume of river flow

**Test Site 12**
- Multiple channels draining sugar cane field
- Some channels appear more turbid than others
- Volume of water significantly reduced
- Thick mud on channel bottom and in fields

**Test Site 13**
- Reformed channel after passing beneath railroad bridge
- Agricultural area
- Sugar cane fields expend beyond test site
- River banks are low
- Some signs of human use of stream besides irrigation
- Tall grasses and trees between river and foot path

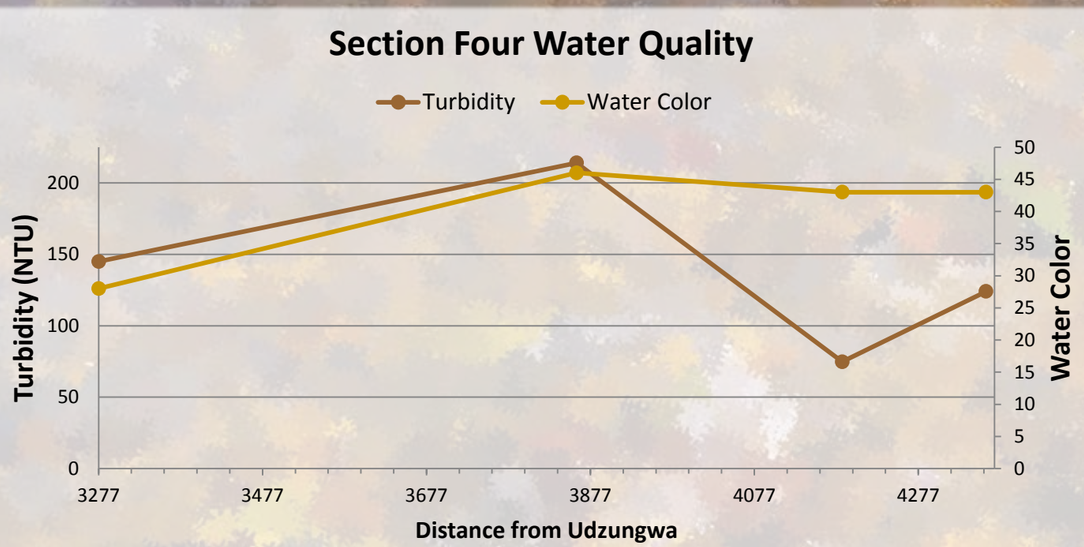
## Issues

### Heavy Irrigation:

After exiting the 0.265 square kilometer section of irrigation, the volume of water flowing through the Njokamoni was noticeably reduced. Much of its water is soaked up or dried up in the irrigation fields. Although it was not explored in this report, decreased availability of water must have implications for water usage downstream. However, it is important to note the economic benefits gained from rice and sugar cane production as a result of irrigation.

### Effects of irrigation on water quality:

Turbidity and water color measurements reached their highest levels in this section of river. Shallow water, huge loads of sediment, frequent soil disturbance by farming and already poor quality water entering the section are likely causes of this trend. Available clean water becomes more scarce downstream of this section because the system of stand pipes does not extend beyond the village.




# Potential Landscape Design to Address Issues

## River Bank Rehabilitation

During data collection, erosion was identified as the largest issue currently facing the Njokamoni River. Several approaches can be taken in addressing stream bank rehabilitation. One of these approaches is the establishment of riparian vegetation, which is used frequently in river management for increasing stream bank stability (Collision and Simon, 2002). Vegetation helps stabilizing banks through increases of soil strength, which is due to the tensile strength and spatial density of its roots (Simon and Darby, 1999). Reestablishment of the natural protections resulting from woody vegetation that provide structure for the river channel as well as protecting riparian structures from disturbance is important for stream quality (Hicks and Reeves, 1993). In choosing the appropriate type of riparian vegetation, hydrological process affecting the stream bank as well as mechanical and ecological criteria must be considered (Simon and Darby, 1999). Attempts at stream bank restoration through the planting of mufufu, or elephant grass, were observed along some sections of the Njokamoni. In these cases, splits of mufufu were planted and staked with bamboo. A native plant with rapid growth rates, deep roots, and uses as cattle feed, establishing this plant in places of heavy erosion may significantly benefit the water quality of the Njokamoni. Any efforts in reestablishing riparian vegetation should be made along the section of stream between test sites three and six, where the cases of erosion are most severe.

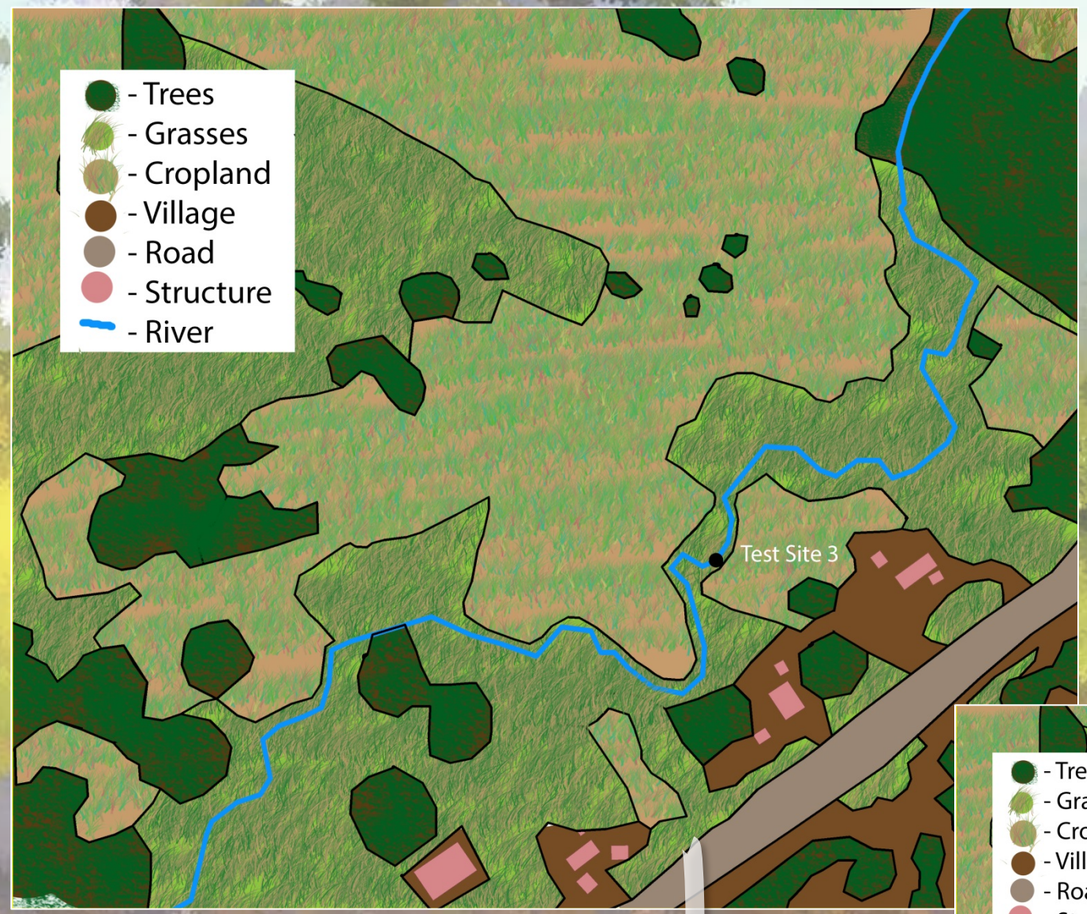
## *Pennisetum purpureum* (mufufu, Elephant Grass)

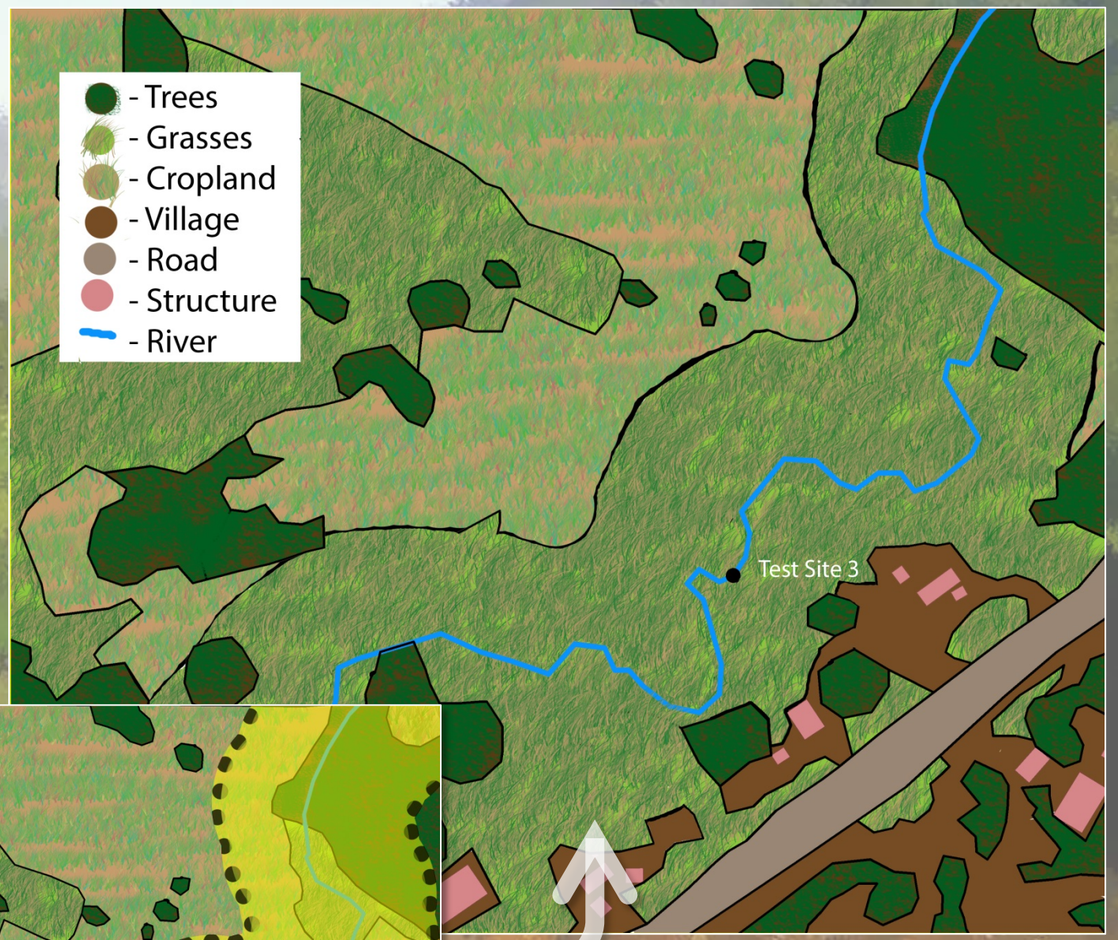
The most common grasses seen along the Njokamoni River are pennisetum purpureum, or mufufu. This perennial is native to Tanzania and grows in large clumps up to 7.5 meters tall. The root system is extensive, penetrating to 4.5 meters. Mufufu is generally found along rivers and forest edges in places with greater than 1,000 millimeters of annual rainfall. It grows best in deep, well-drained soils. Mufufu is often planted to produce high yields of hay, which is extremely palatable to livestock. Typically the grass is harvested by cutting approximately 15 centimeters from base of stem and is then carried off in bundles.

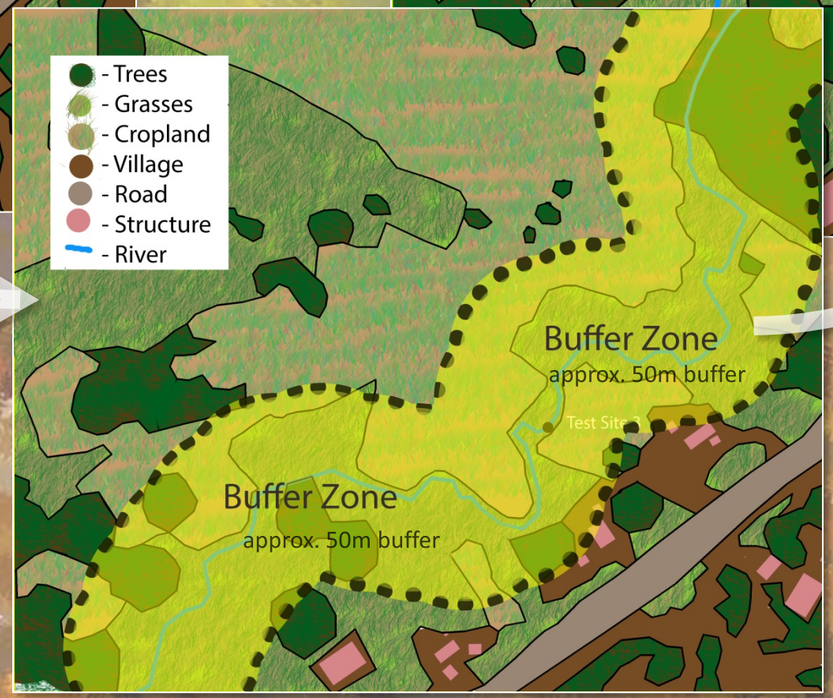
Mufufu can be established from seeds, but is typically planted from setts, cuttings, or splits. It normally spreads through rhizomes and fallen stems taking root at the nodes. For soil conservation, close spacing is required and in high rainfall environments contour hedgerows are recommended.

(information retrieved from www.tropicalforages.info, June 12, 2013)

# Potential Landscape Design to Address Issues




## River Corridor Buffer

Although measurements of runoff from storm water were not taken during this project, the high sediment loads within the Njokamoni suggest runoff is a serious issue. It is likely that pollutants from villages, latrines and animal waste are also entering the river during these events. A corridor designated exclusively for riparian vegetation larger than the five foot buffer already required may help address these issues.

## Effects of River Corridor Buffer on Land Use Near Test Site 3

# Njokamoni as an Indicator
## For Rivers Along Eastern Edge of UMNP


The information provided in this report will be valuable in future planning and design decisions in the area around the Njokamoni River. Patterns identified on the Njokamoni are representative of other rivers and streams in the area, and lessons learned here can be applied elsewhere, especially along the Udzungwa Mountains National Park/Kilombero Valley interface. This area is characterized by rivers which form in the Udzungwa Mountains and then flow through communities along the edge of the park.

One can expect each of these rivers follow a general pattern similar to the Njokamoni. The service of protecting the headwaters that is provided by the forest results in high quality water upon exiting the park, which is immensely valuable as safe drinking water. The water quality rapidly degrades as it passes through a primarily agricultural area. Sections of rivers with prevalent human activity experience higher rates of diminishing water quality and severe erosion along riverbanks is likely. Establishing riparian vegetation will be valuable for riverbank stabilization and runoff filtration. Human use of the rivers is important for fishing, resources and domestic water use. Eventually, the river will be used for irrigation of rice paddies and sugar cane fields.

Understanding these patterns is important when considering landscape design. The challenges faced by each river will vary to some degree, and nothing will provide a better understanding of a place than in-the-field observations, but the story of the Njokamoni will serve as a basis for further exploration.

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**June, 2013**

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# Appendix

1. turbidity and water color data
2. presentation slides

| Test Site | Distance from Udzungwa (meters) | Turbidity (NTU) | Water Color (APHA Cobalt) |
|---|---|---|---|
| 1 | 0 | 3.96 | 2 |
| 2 | 252 | 6.43 | 6 |
| 3 | 886 | 13.6 | 8 |
| 4 | 1150 | 18.5 | 9 |
| 5 | 1744 | 68.0 | 10 |
| 6 | 2161 | 95.2 | 24 |
| 7 | 2299 | 45.0 | 9 |
| 8 | 2669 | 140 | 38 |
| 9 | 2945 | 64.9 | 20 |
| 10 | 3277 | 145 | 28 |
| 11 | 3860 | 214 | 46 |
| 12 | 4184 | 74.8 | 43 |
| 13 | 4360 | 124 | 43 |

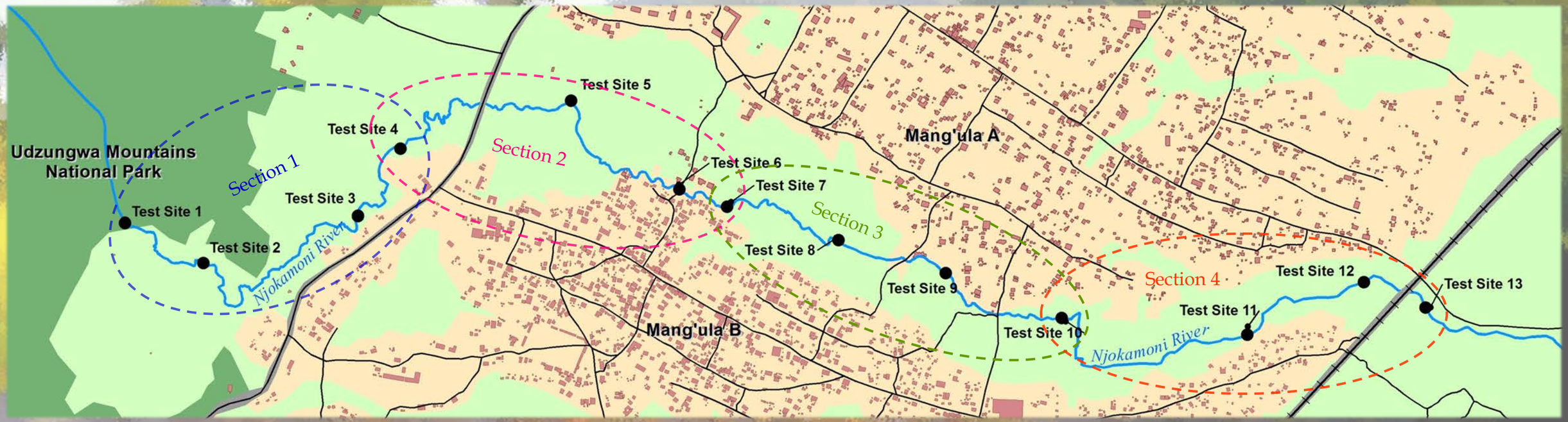
# Understanding Njokamoni

## River Study, Spatial Patterns, Issues and Potential for Landscape Design

Aaron Dennis

# Project Overview

## Report on Njokamoni issues, spatial patterns, water quality and potential for landscape design.




- Source in Udzungwa Mountains
- Length of studied river corridor: 4.36 km
- Approximate total catchment area of studied corridor: 1,300 hectares
- Enters Kilombero River, to Great Ruaha River, to Rufiji River, to Indian Ocean
- 2,000 mm of rainfall annually
- Two rainy seasons: long rains March-May, short rains November-December

# Issues affecting Water Quality

## 1. Riverbank Erosion

- the most serious immediate threat to the Njokamoni, it causes unstable river banks, loss of crop land and sedimentation

## 2. Agricultural Runoff

- heavy rains in the wet season combined with intensive land use causes significant runoff events and sedimentation

## 3. Village Waste

- debris, trash, and human/animal waste entering the river from house compounds in the village affects water quality

## 4. Irrigation

- high-volume withdrawals of water and disturbance of muddy river bottom through farming contribute to poor river quality

## 5. Fishing

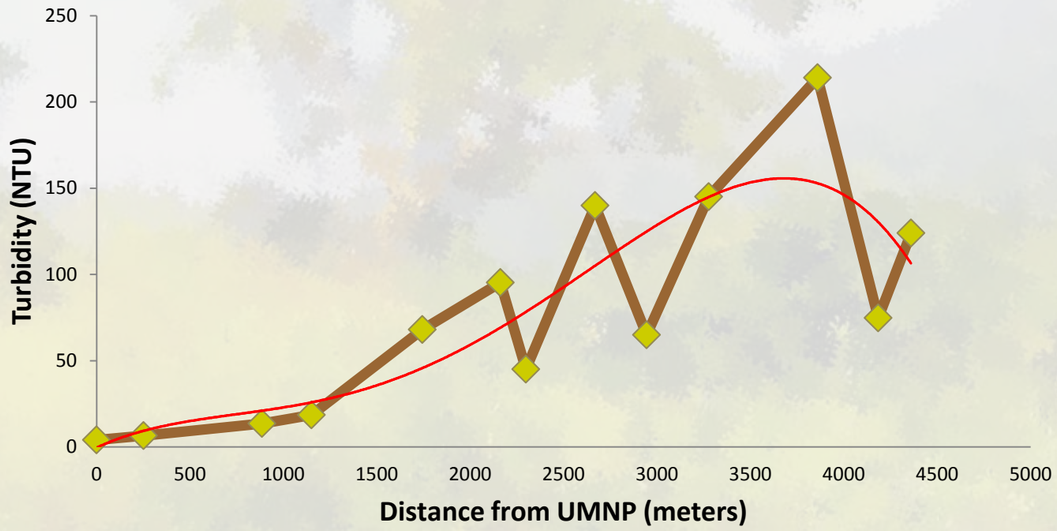
- fishing is intensive in some section of river and activities such as access and dams affect water quality

## 6. Sand Extraction

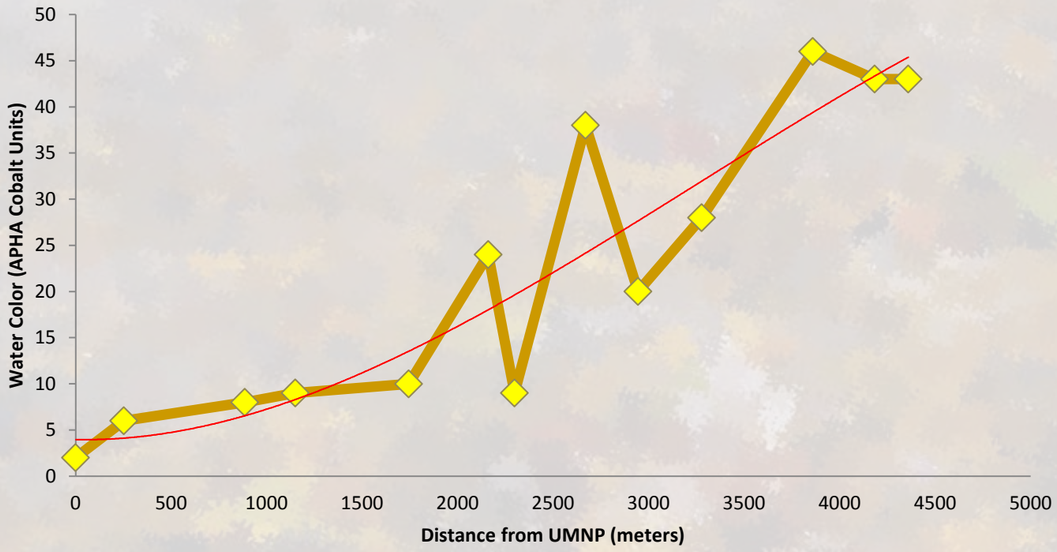
- although important as building material, sand extraction acts as catalyst for erosion processes

# Njokamoni Water Quality

## Turbidity




## Water Color




## Water Quality Data and Discussion

**Turbidity:** water clarity and how much material suspended in water

**Sources of Turbidity:** soil erosion, run off, waste discharge

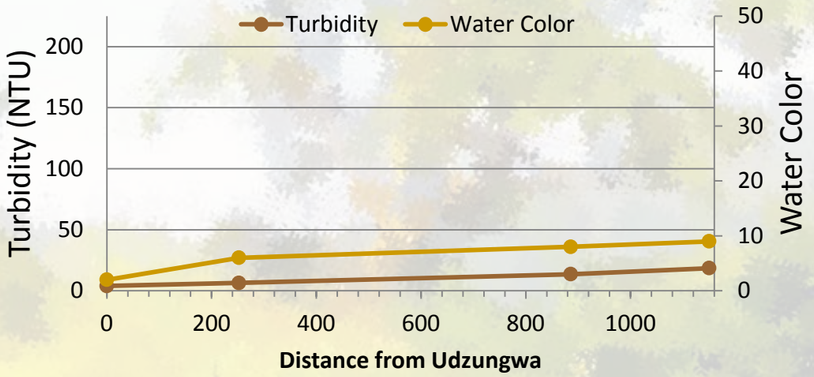
1 NTU = clear mountain stream
10 NTU = calm river, no rain
100+ NTU = river during runoff events

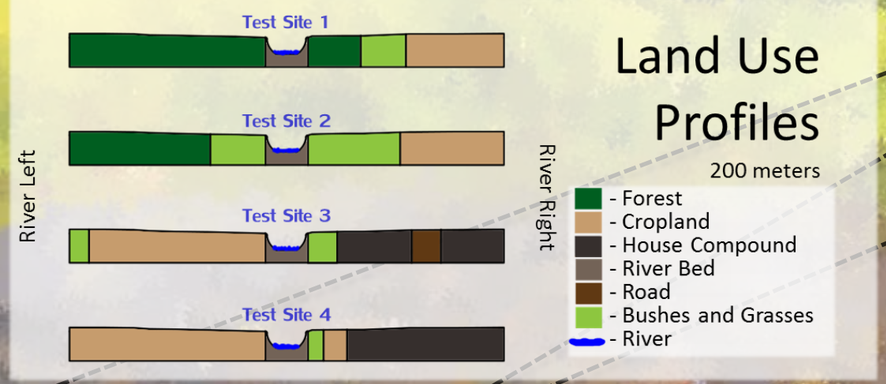
**Water Color:** measurement of yellowness, clear indicates purity and yellow indicates sediment and organic matter

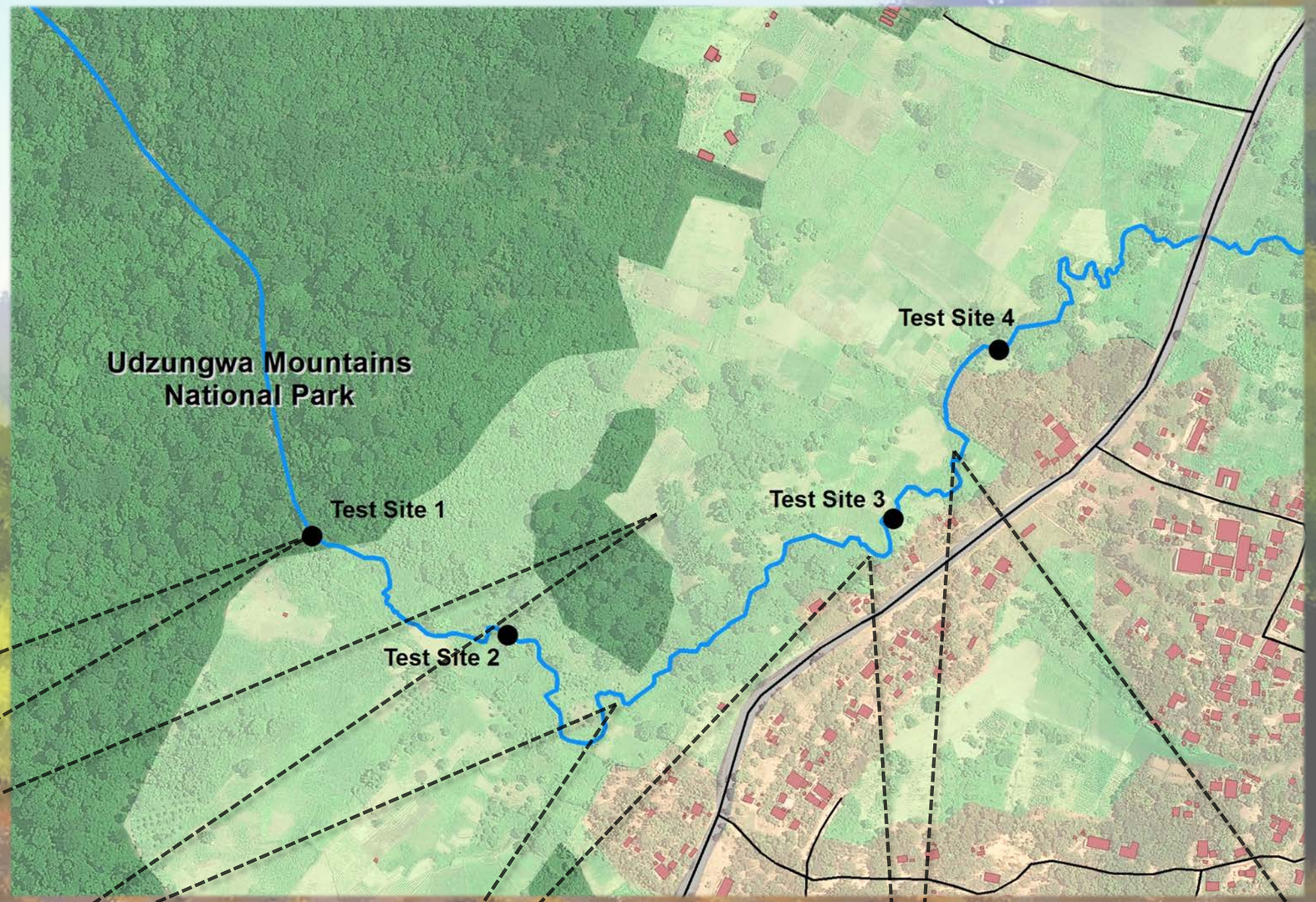
## Ecosystem Services & Health

# Section One

## (Test Site 1 to Test Site 4)




River leaving Udzungwa over boulders

Piped river water used for irrigation

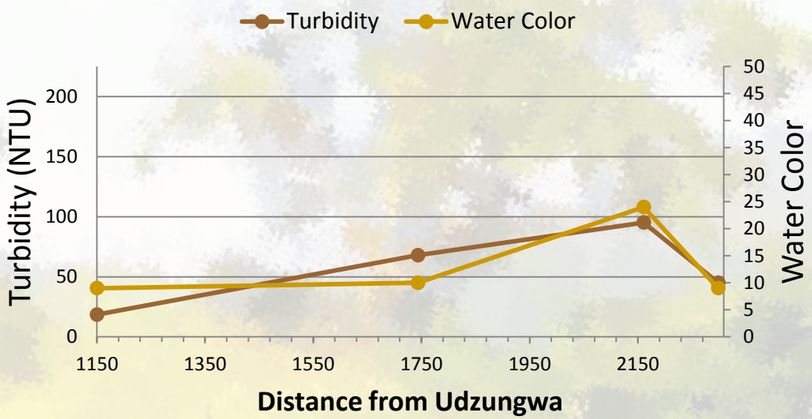
Small dam on river for fishing and irrigation

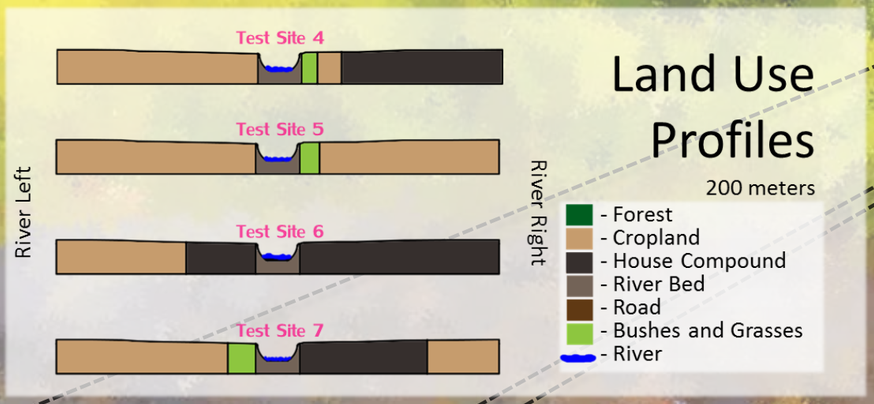
Debris from residential area washing into river

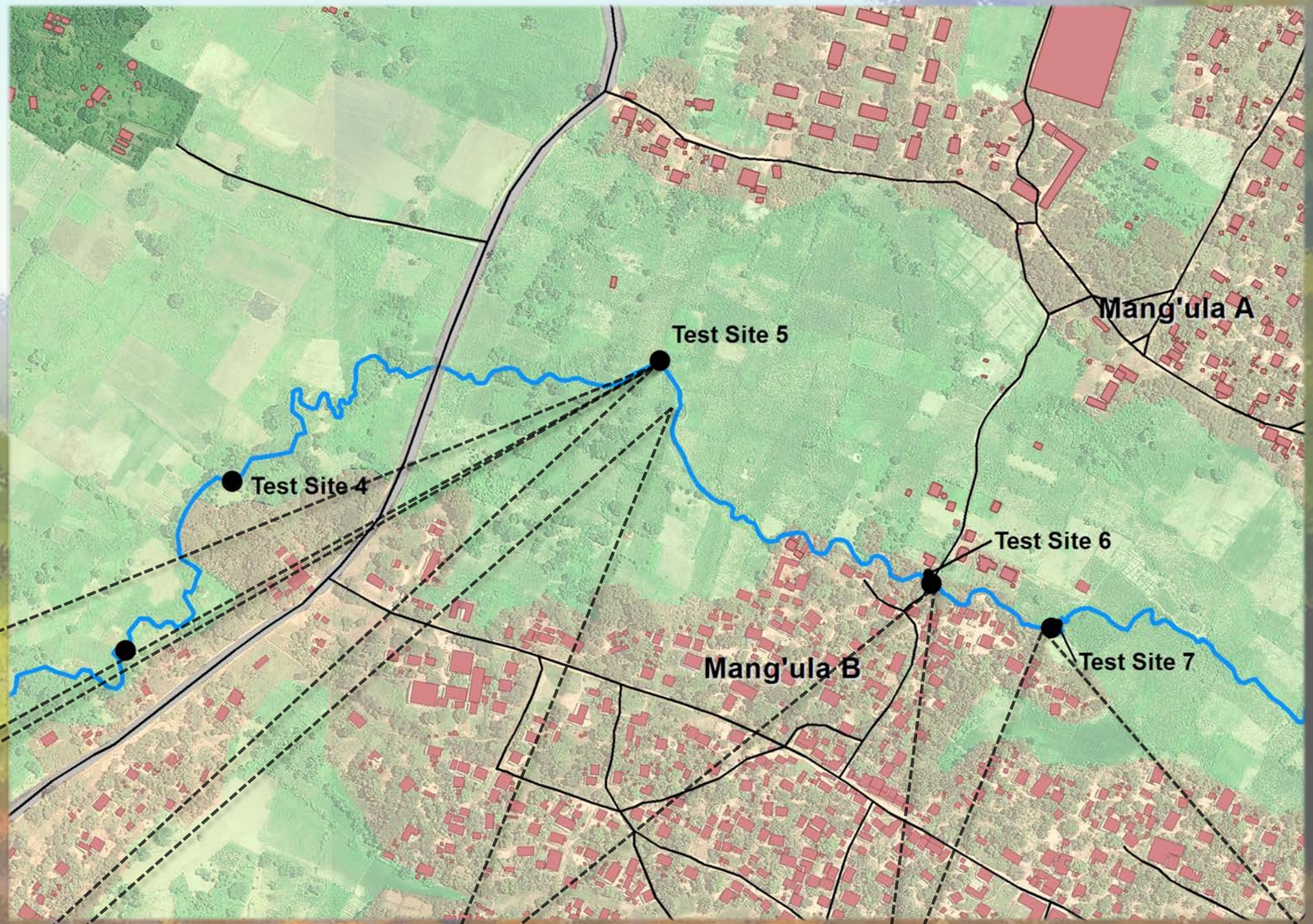
Elephant grass plantings on eroded river bank

# Section Two

## (Test Site 4 to Test Site 7)




Severe erosion on outside bend of river

Stagnant water along edge of river

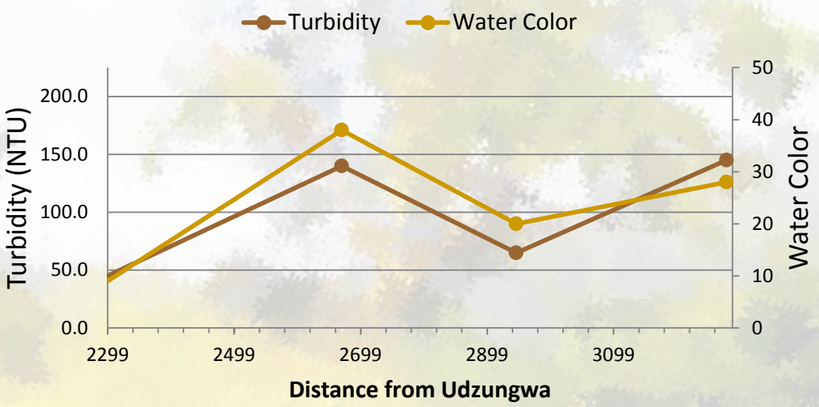
River used for washing clothing and dishes

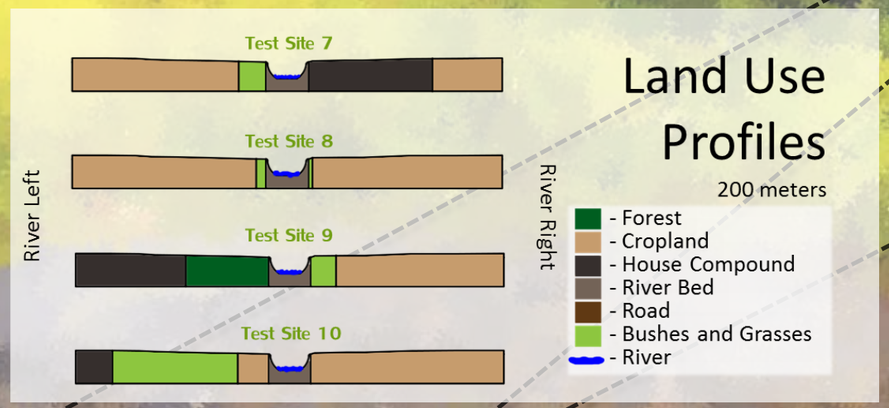
Bridge in Mang'ula B

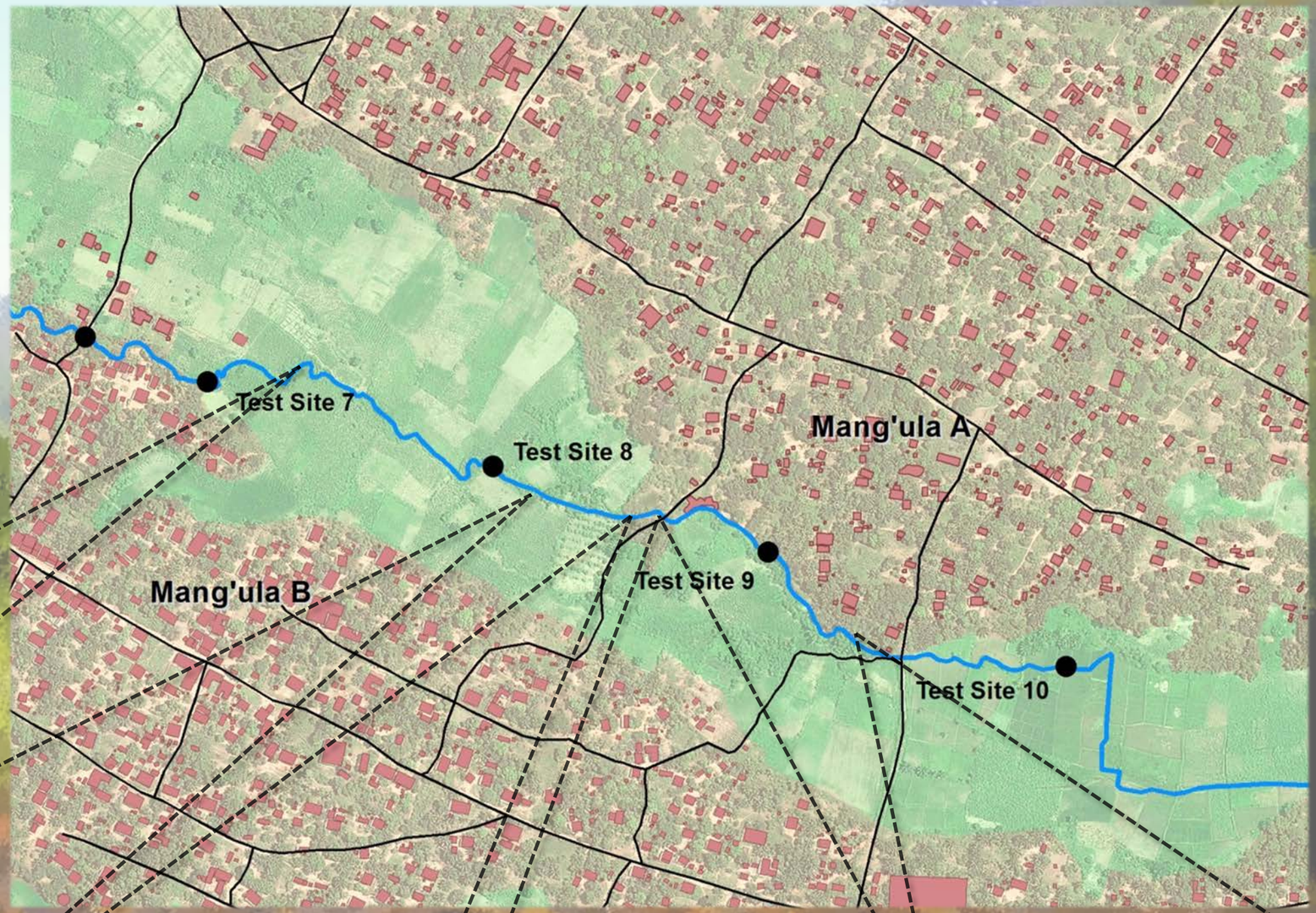
Stream channel exiting Mang'ula B

# Section Three

## (Test Site 7 to Test Site 10)




Channel widening through river bend near maize field

Dam and fish trap

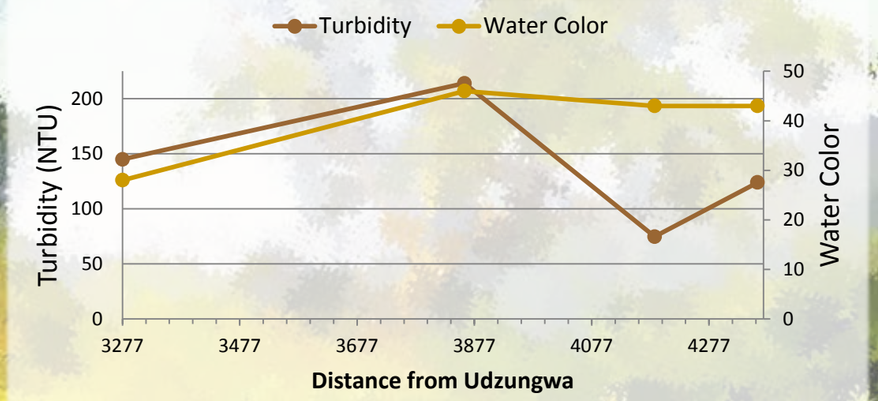
Fishing with net

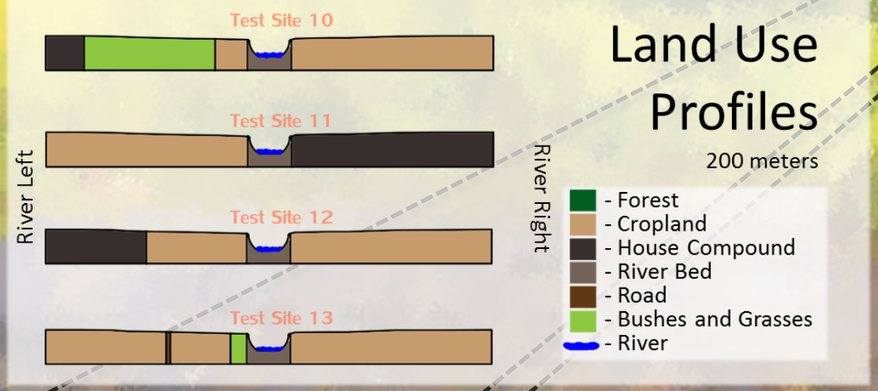
Crossing point on path between Mang'ula A and Mang'ula B

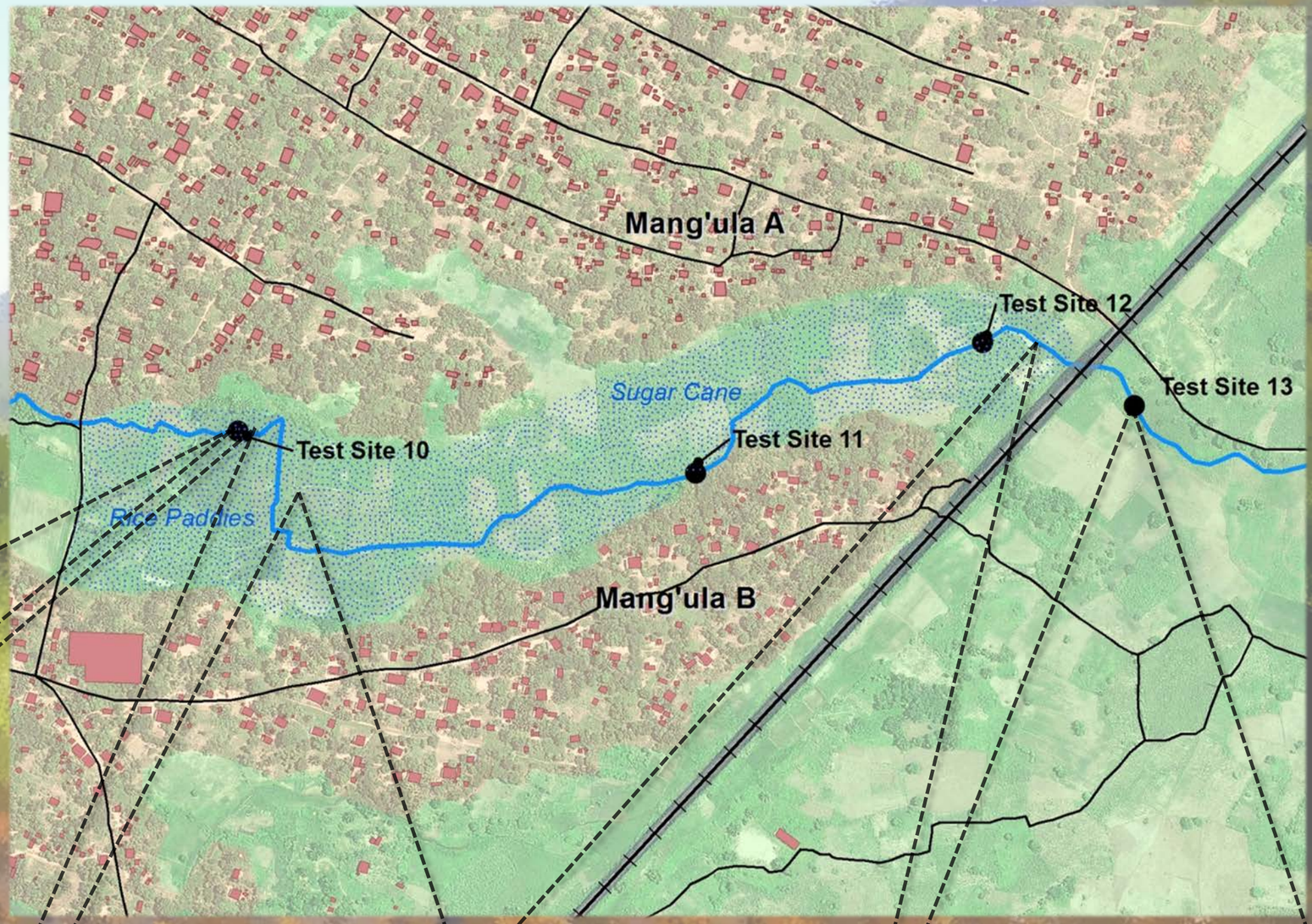
Deep and slow section of river popular for fishing

# Section Four

## (Test Site 10 to Test Site 13)




Last remnants of river channel before full irrigation

River being redirected into fields for irrigation

Rice paddies

Channel reforms after sugar cane fields

Final test site after railroad bridge

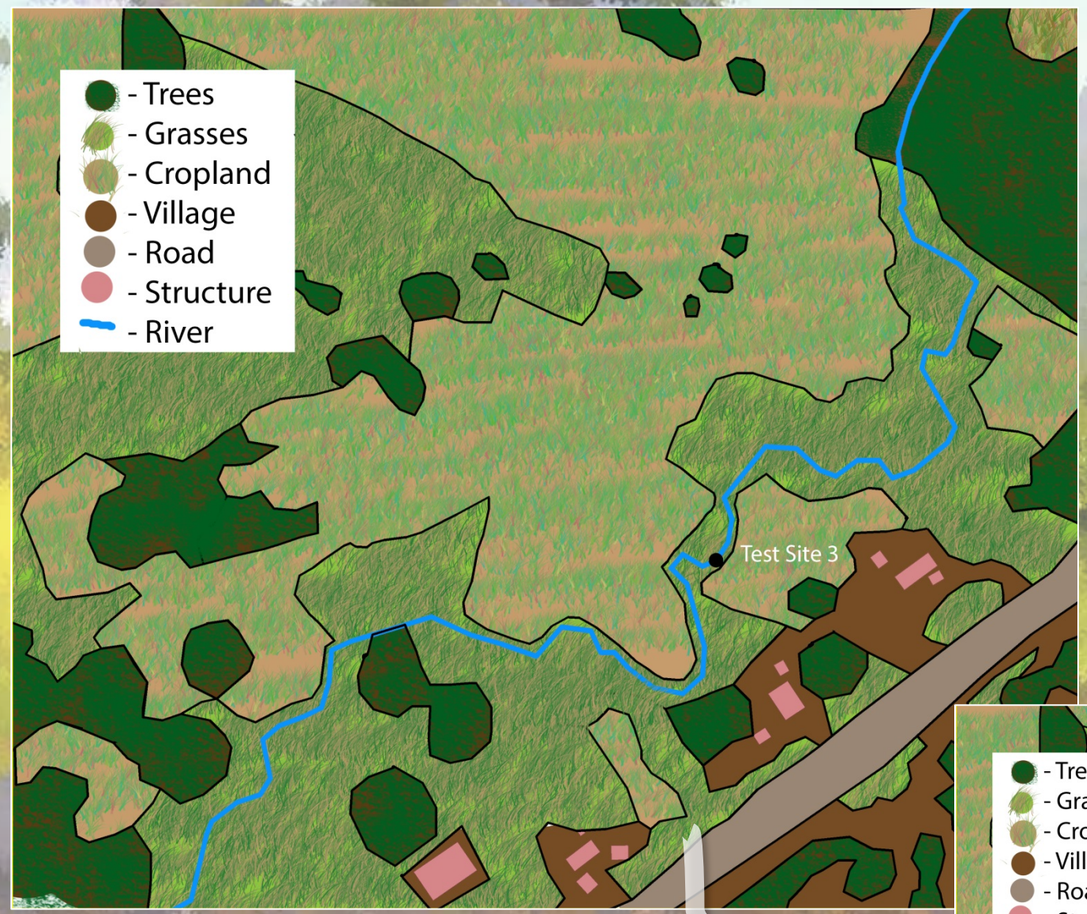
# Potential Landscape Design to Address Issues

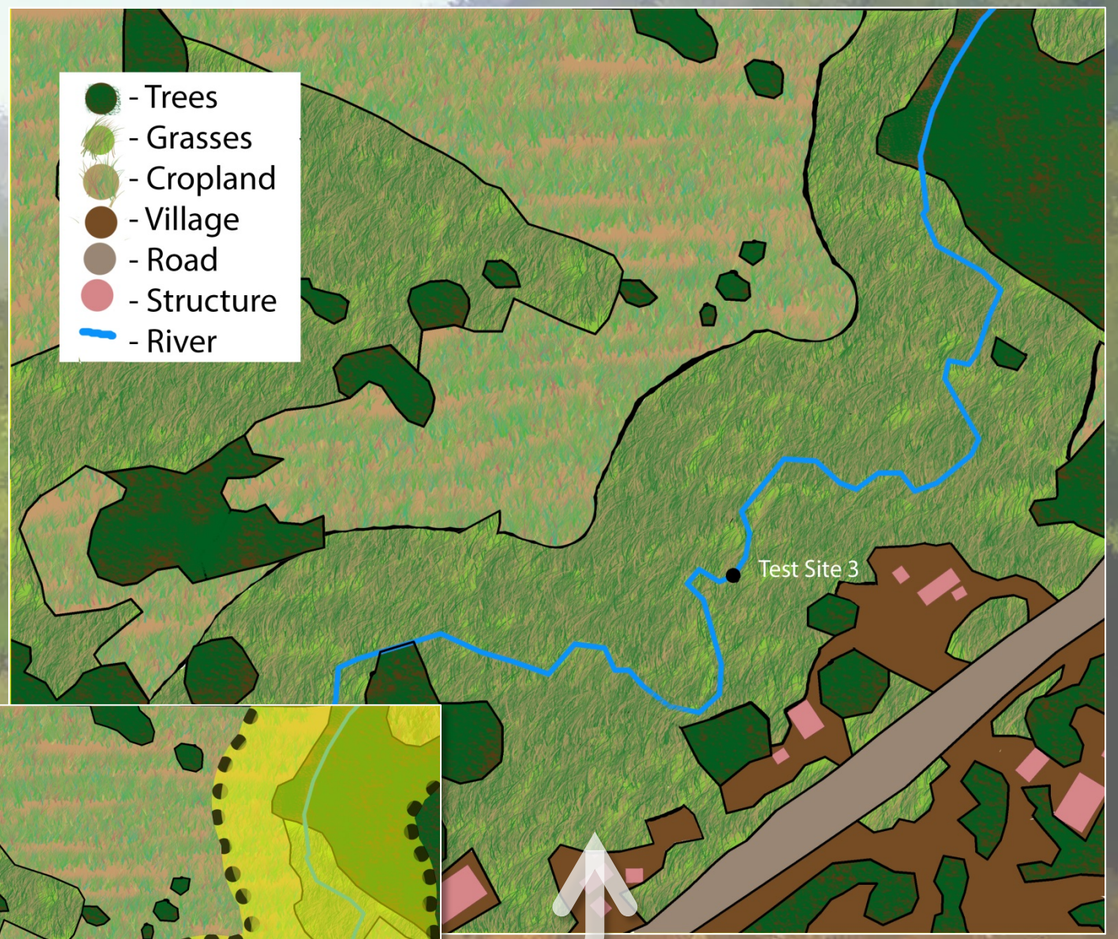
## Riverbank Rehabilitation

Severe riverbank destabilization may be addressed through riparian vegetation. Mufufu, or elephant grass, is native, fast growing, has a deep root structure, and can be used for cattle feed. Planting should be focused near test site five.

*Pennisetum purpureum*
(mufufu, Elephant Grass)

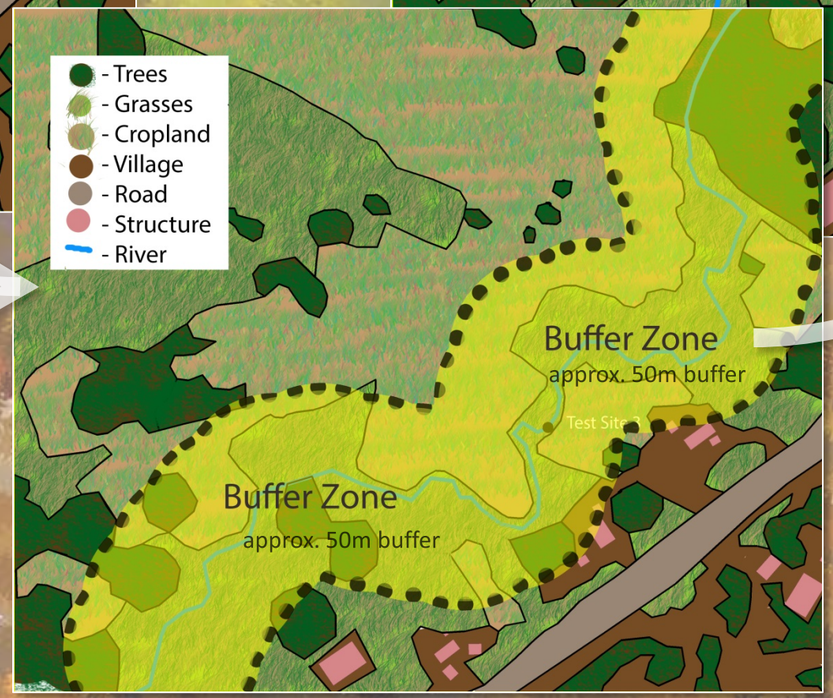
# Potential Landscape Design to Address Issues



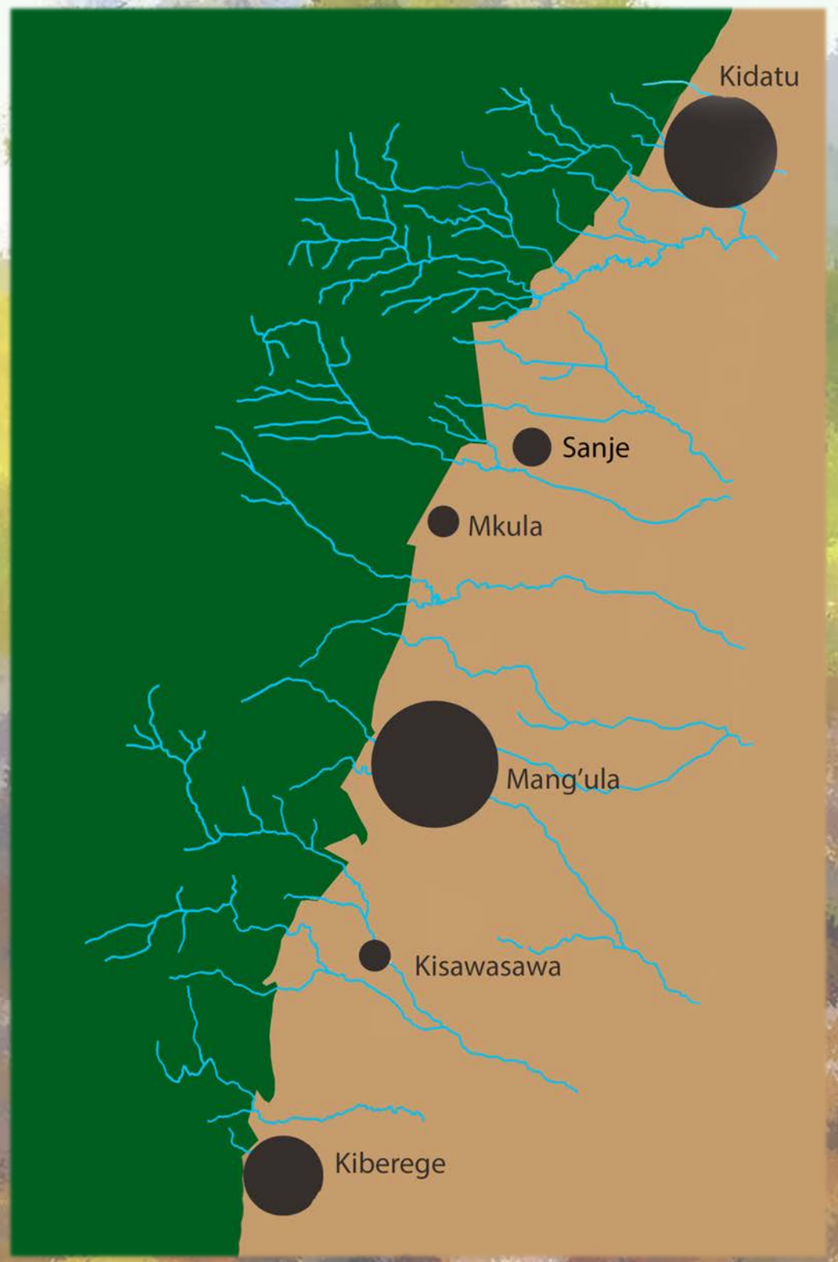

## River Corridor Buffer

High sediment loads within the Njokamoni suggest runoff is a serious issue. Pollutants from villages, latrines and animal waste are entering the river during these events. A corridor designated for riparian vegetation may address these issues.




## Effects of River Corridor Buffer on Land Use Near Test Site 3

# Njokamoni as an Indicator
## For Rivers Along Eastern Edge of UMNP




**Njokamoni River = template for other rivers in area**

1. Headwaters protected by forest provide high water quality
2. Water quality declines in agricultural area
3. Water quality declines faster near developed land
4. Quantity and quality decline when used for irrigation

Potential landscape design: riparian vegetation, riverbank stabilization, river corridor buffer

**Issues different on each river, but patterns of Njokamoni serve as basis for exploration.**

**Created by**

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**June, 2013**

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