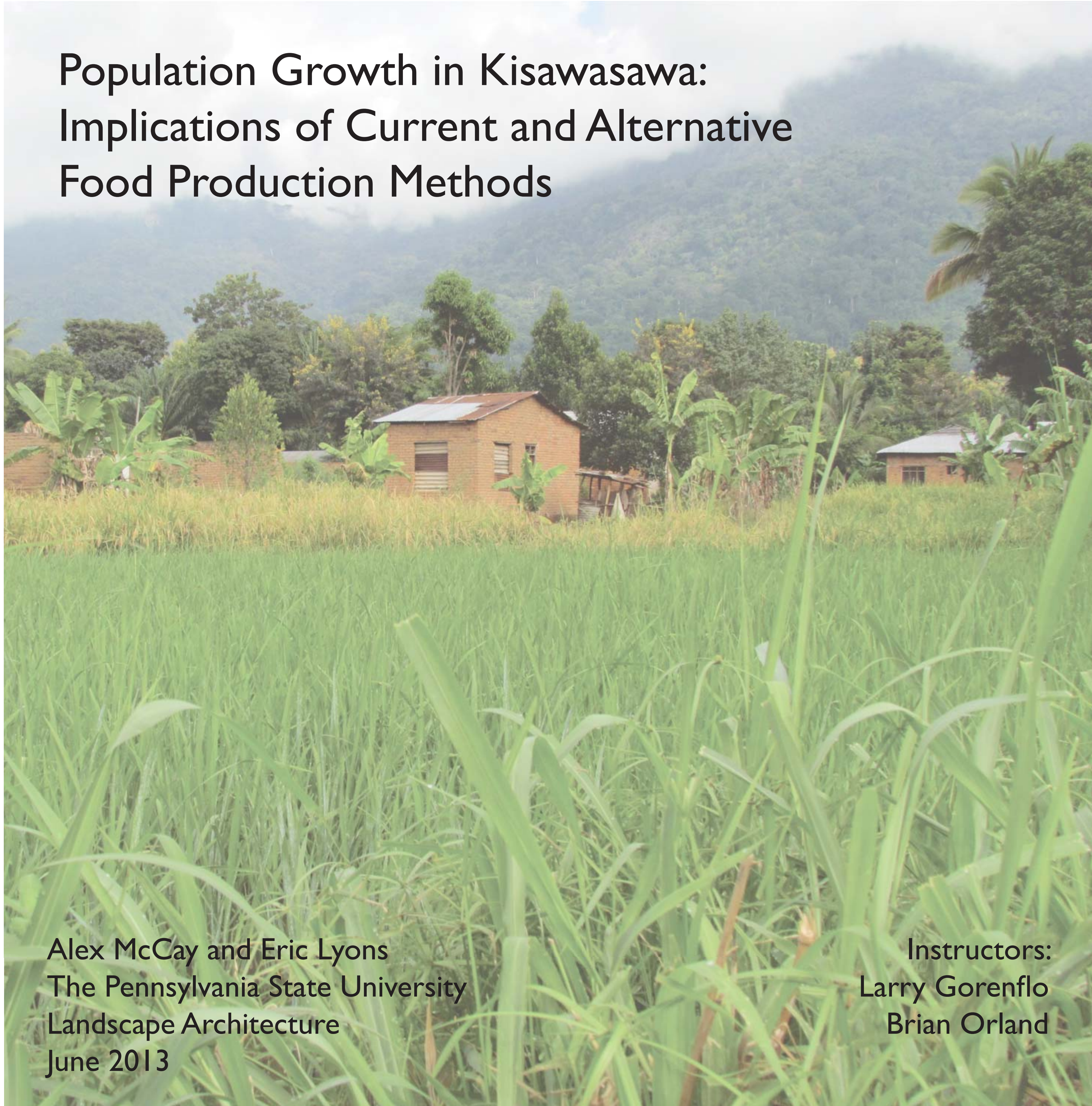
Population Growth in Kisawasawa: Implications of Current and Alternative Food Production Methods



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Site Context

Background:

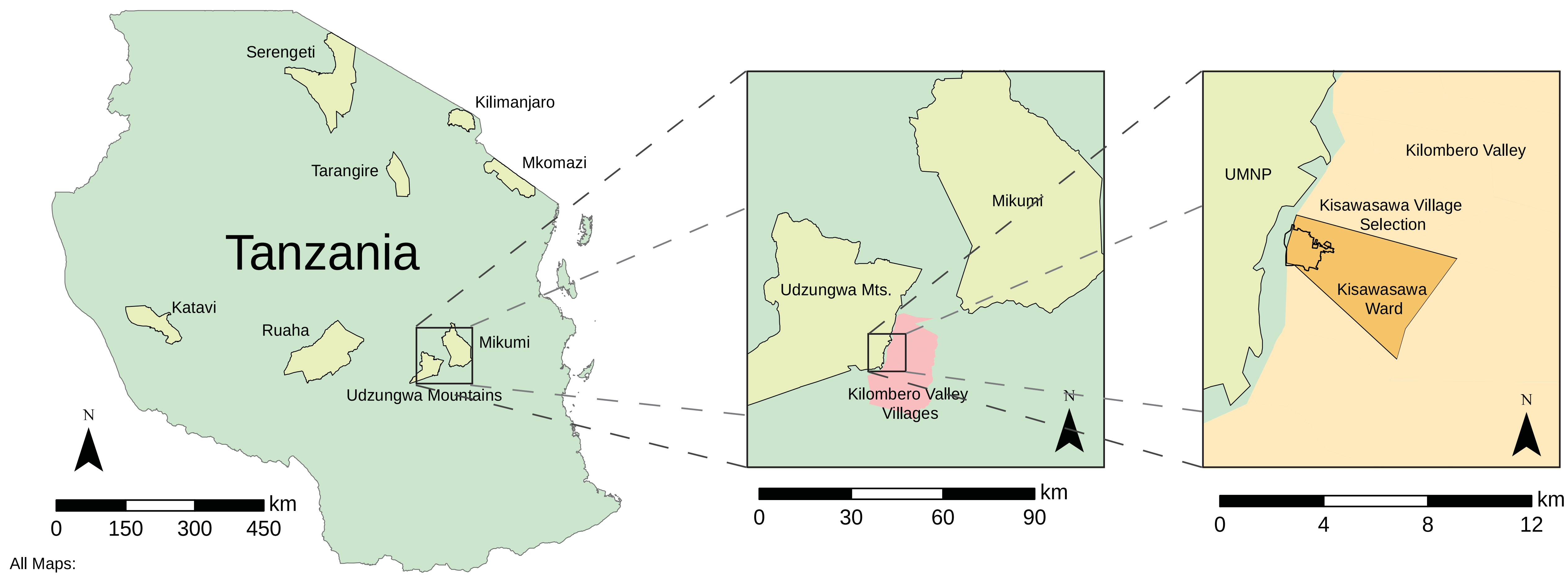
The Kilombero Valley is located in eastern Tanzania, South of Mikumi National Park at the eastern foothills of the Udzungwa Mountains National Park. The area is rich in biodiversity with a high number of endemic species and protected land. The local population consists of developing villages whose main economic means are agricultural production. Dependence on natural resources has made a large impact on the local land particularly in regard to forest land depletion.

Agricultural Production:

Current land use is dominated by agriculture in the form of cash crops and on a smaller scale subsistence farming.

Population growth: 3.7%

High rates of fertility and in-migration have the area growing at a rapid rate.



All Maps:
Projection: Cylindrical_Equal_Area
Data Set: LArch 499F

Focus Location: Kisawasawa

Kisawasawa Village:

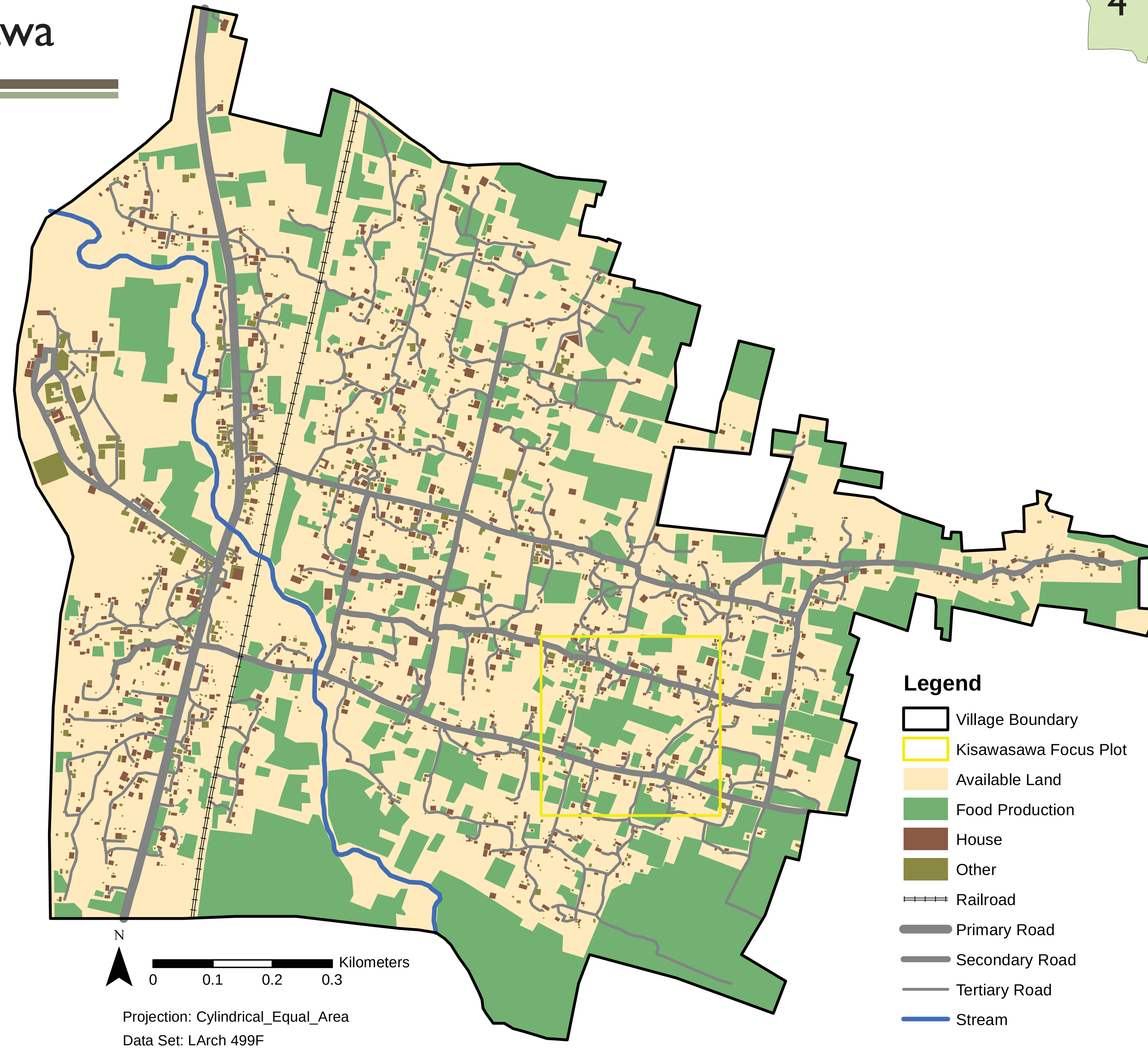
Kisawasawa was selected as a representative village to get a detailed look at food security and population growth. Since the main area of the village is essentially land locked between the UMNP and un-inhabitable wetlands, a fixed boundary was created. Looking at the future possibilities, Kisawasawa provides a model study of subsistence food production that can be explored throughout the rest of the Kilombero Valley as populations increase.

- Higher rate of population growth: 5.7%
- Layout on an informal grid system
- Available land (non-commercial use) 62.9%

Population Growth +

Food Production +

Available Land −



Projection & Design focus

As the security of food and resources are paramount to the health of Kisawasawa, we focused our analysis and design on a 40 year projection of population growth in the village. We created 3 scenarios, each with a different means of agricultural production affecting land needs for subsistence farming, and how that need subsequently opened the door for design and planning to create a more efficient future that is better acclimated to accommodate for such growth.

Scenario 1

Current Shamba System

Scenario one looks at business as usual; without any attempts to better design or plan for growth we see the effects of current land use and agricultural practices, along with their effect on the villages ability to supply for a carrying capacity equal to its current levels. Expansion in this scenario will be based off the average current land and shamba allocation per household.

Design: Organic

Scenario 2

Drip Irrigation System

Scenario 2 looks at increased agricultural production through drip irrigation as a way to decrease land needed to sustain current food production levels. The scenario assumes full implementation of drip irrigation on all subsistence land and that all land no longer in agricultural production will be converted to fuelwood reserve until carrying capacity is met. At that point, fuelwood reserves will be converted to residential land with accompanying shamba plot until all available land is depleted. Tanzanian planning regulations on roadways will also be accounted for, further decreasing available land from Scenario 1. Scenario 2 also implies the same allocation ratio as above.

Design A: Community Based

Design B: Individual Based

Scenario 3

Aquaponics System

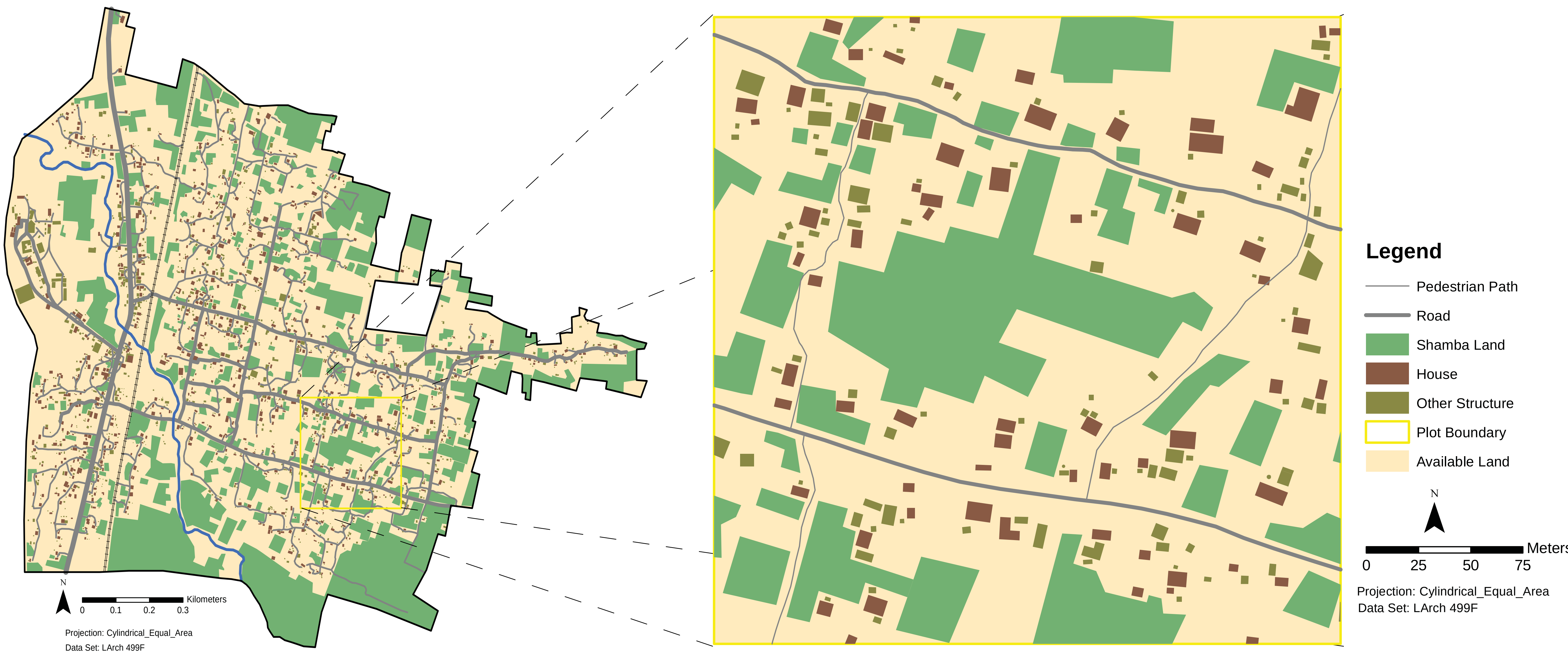
Scenario 3 applies highly efficient aquaponics as a replacement for subsistence field cultivation. As in scenario 2, all land no longer in agricultural production will be converted to fuelwood reserve until carrying capacity is met at current production levels. At that point fuelwood reserves will be converted to residential land with aquaponics system until all available land is depleted. Tanzanian planning regulations in accordance to roadways will also be followed in this scenario. Scenario 3 also implies the same allocation ratio as above.

Design A: Community Based

Design B: Household Based

Representative Area

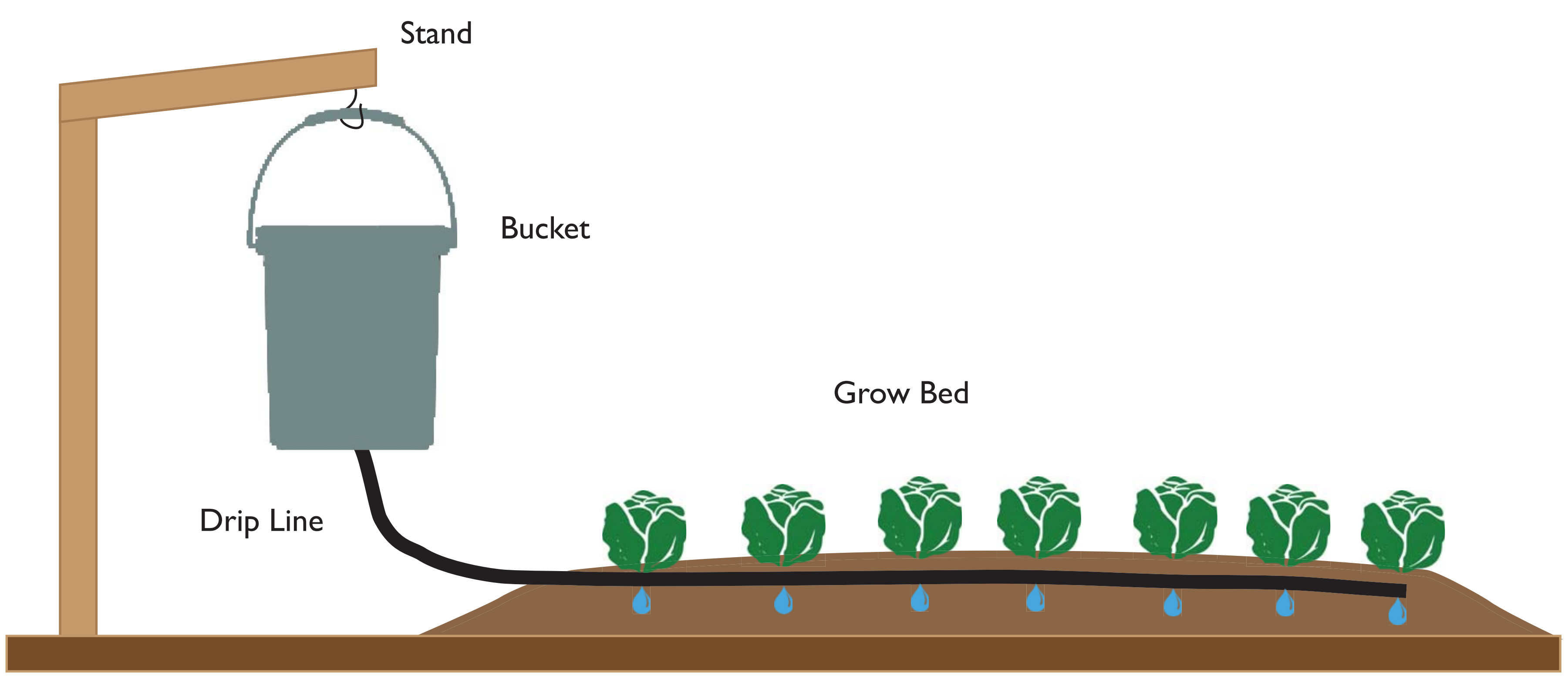
To model the three scenarios mentioned, a 300m x 300m focused representative area within Kisawasawa was selected. Focusing on a specific location in the village, allows for better understanding of impacts that will occur over the projected time period. A scaled down approach will provide a visualization of the implications that each design could have on the future of Kisawasawa.



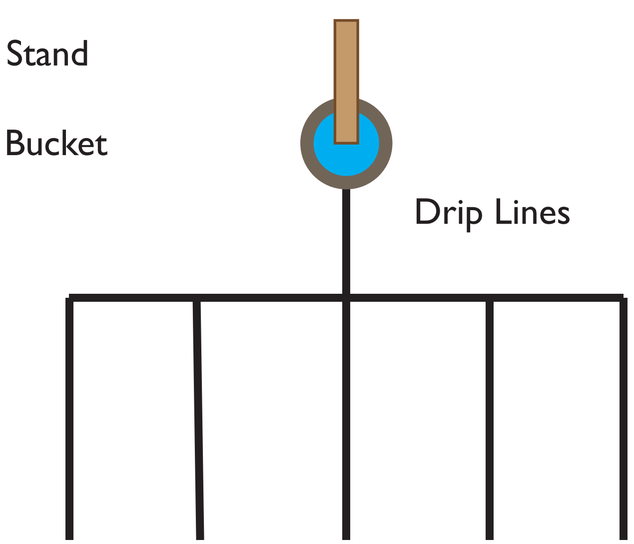
Drip Irrigation

System Overview

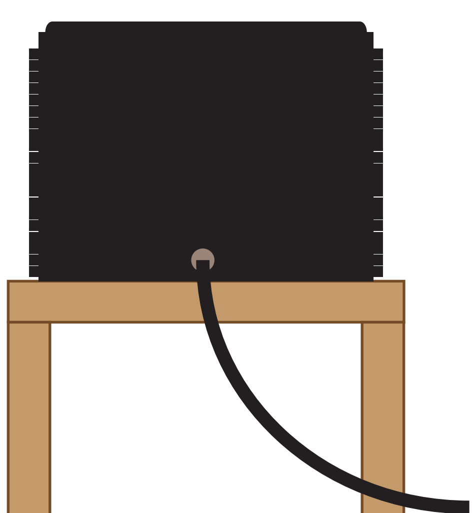
Section



Plan



Adaptations



Bucket

A water source device is elevated from a stand and supplies water down the drip lines creating a continuous and consistent water application to crops

Water

Water is applied directly to the roots at measured amounts, requiring significantly less water (30-70%), and fertilizer than conventional methods.

Crops

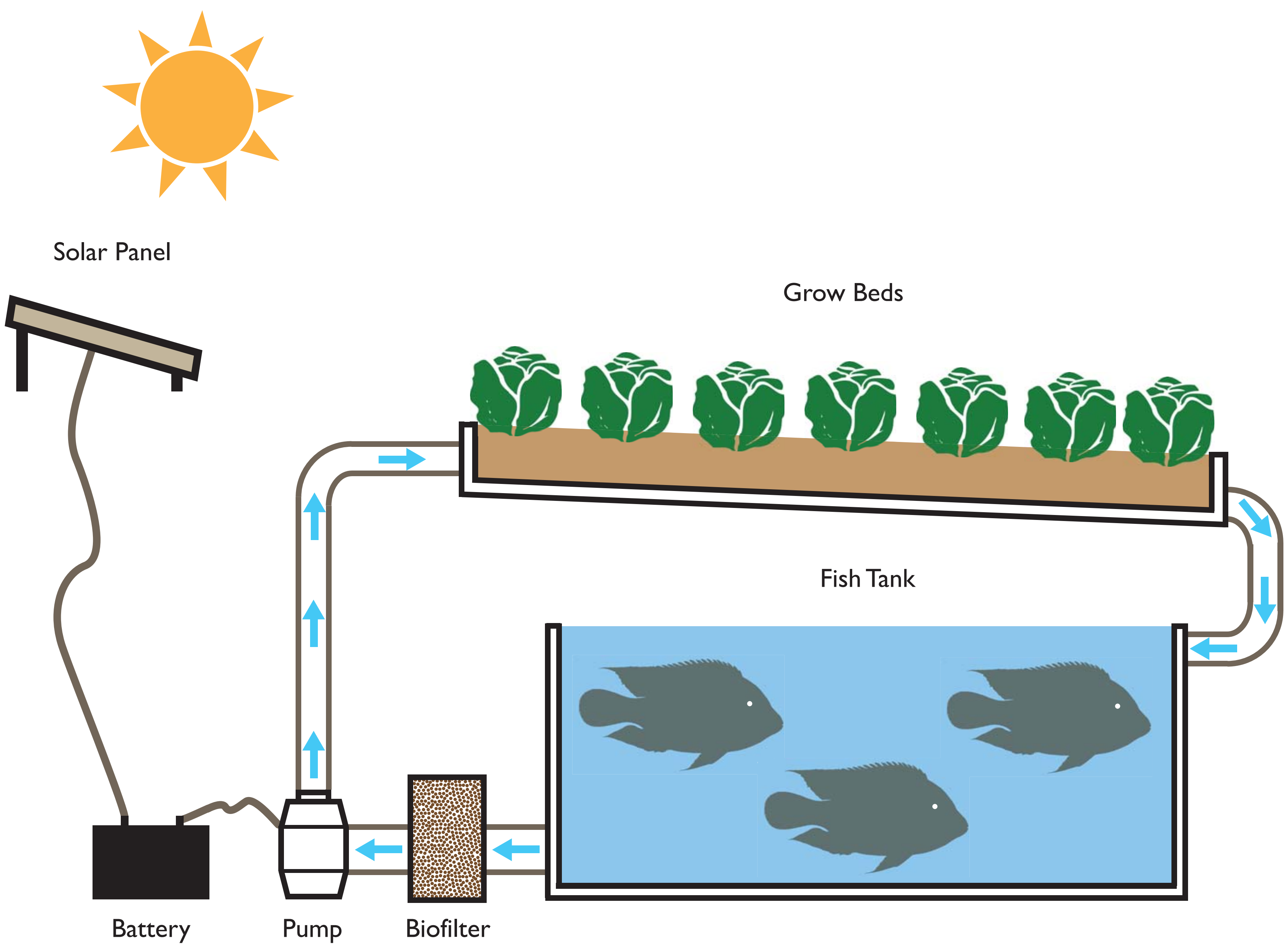
With calculated water and fertilizer application by drip irrigation, production is on average increased by 54%, better utilizing space and increased income potential.

Scale

Drip irrigation is scalable based on plot area. With variations in water capacity and equipment size this technology can be scaled up or down to meet specific space needs.

Aquaponics

System Overview



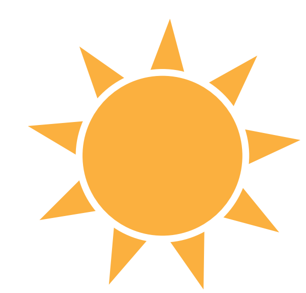
Fish

Nutrients in the fish waste are used to fertlize the plants, increasing growth rates. The growth of fish as well provides increased accessibility to a protein source or marketable food product.

Crops

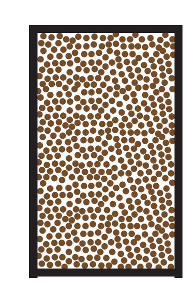
Crops, with increased water and nutrient flows, grow at nearly twice the rate of conventional methods. In doing so they also filter the water in the system. The ability to grow a variety of crops offers the ability to provide uncommon products that could increase income potential.

Energy

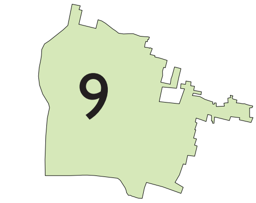


Energy to consistently power water circulation is crucial. Various energy sources can be utilized but continual access needs to be maintained.

Filtration



A biofilter uses bacteria cultures to break down the fish waste separating the solid material from the nutrients. The solids will be removed, and can be used as a source of fertilizer outside of the system.



Fuelwood Reserves

Available land from agricultural production increases will be converted to fuelwood lots. These lots will be planted to provide the maximum amount of available fuel and harvested at a 3 year interval that will provide for a proportion of incorporated agricultural production to occur during the harvest cycle until canopy becomes completely closed.

Tree Species:
Acacia Crassicarpa

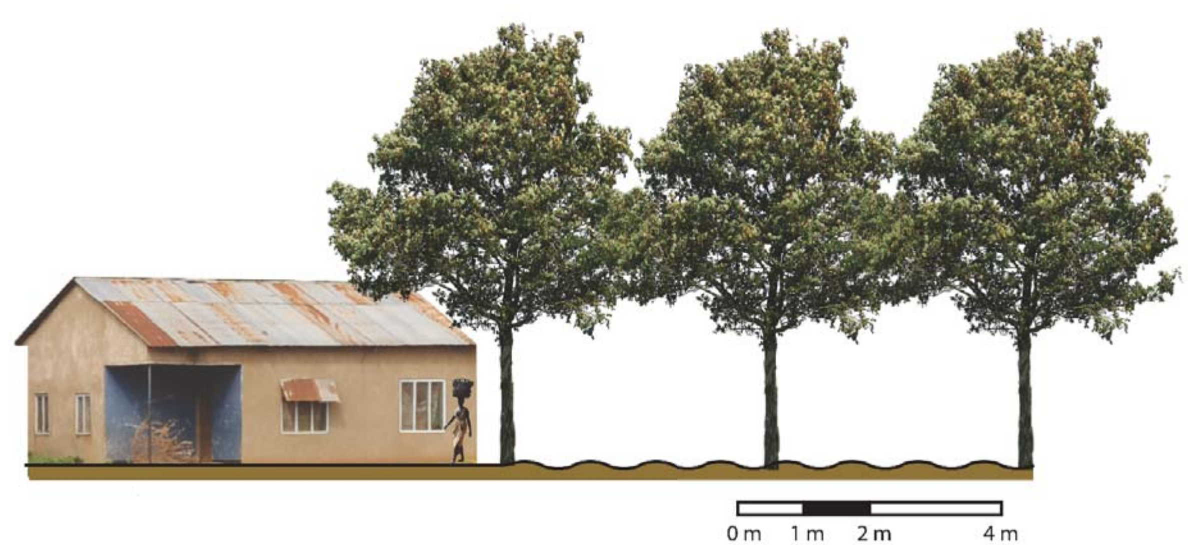
Agricultural
Production per Cycle:
53%

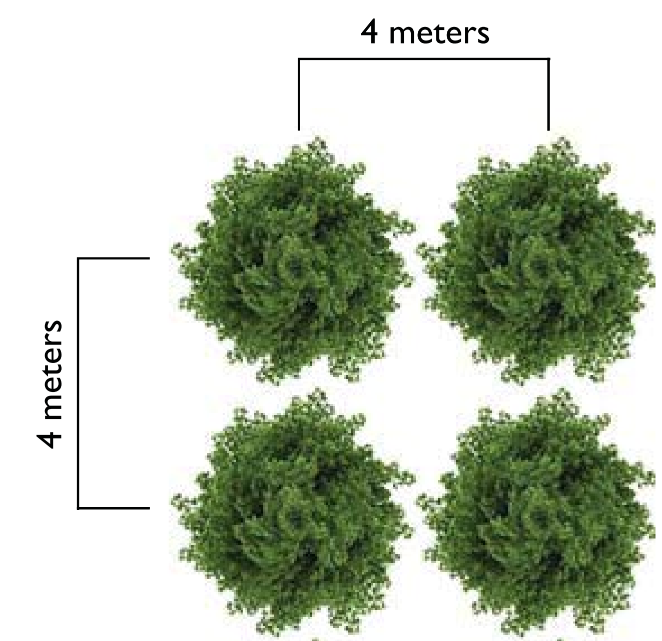
Space Maximization:
- 4m x 4m spacing
- 625 trees/Ha

Year 1:
- Plant tree saplings
- Crop Production: 100%

Year 2:
- Partial canopy cover
- Crop Production: 60%

Year 3:
- Canopy cover & harvest
- Crop Production: 0%

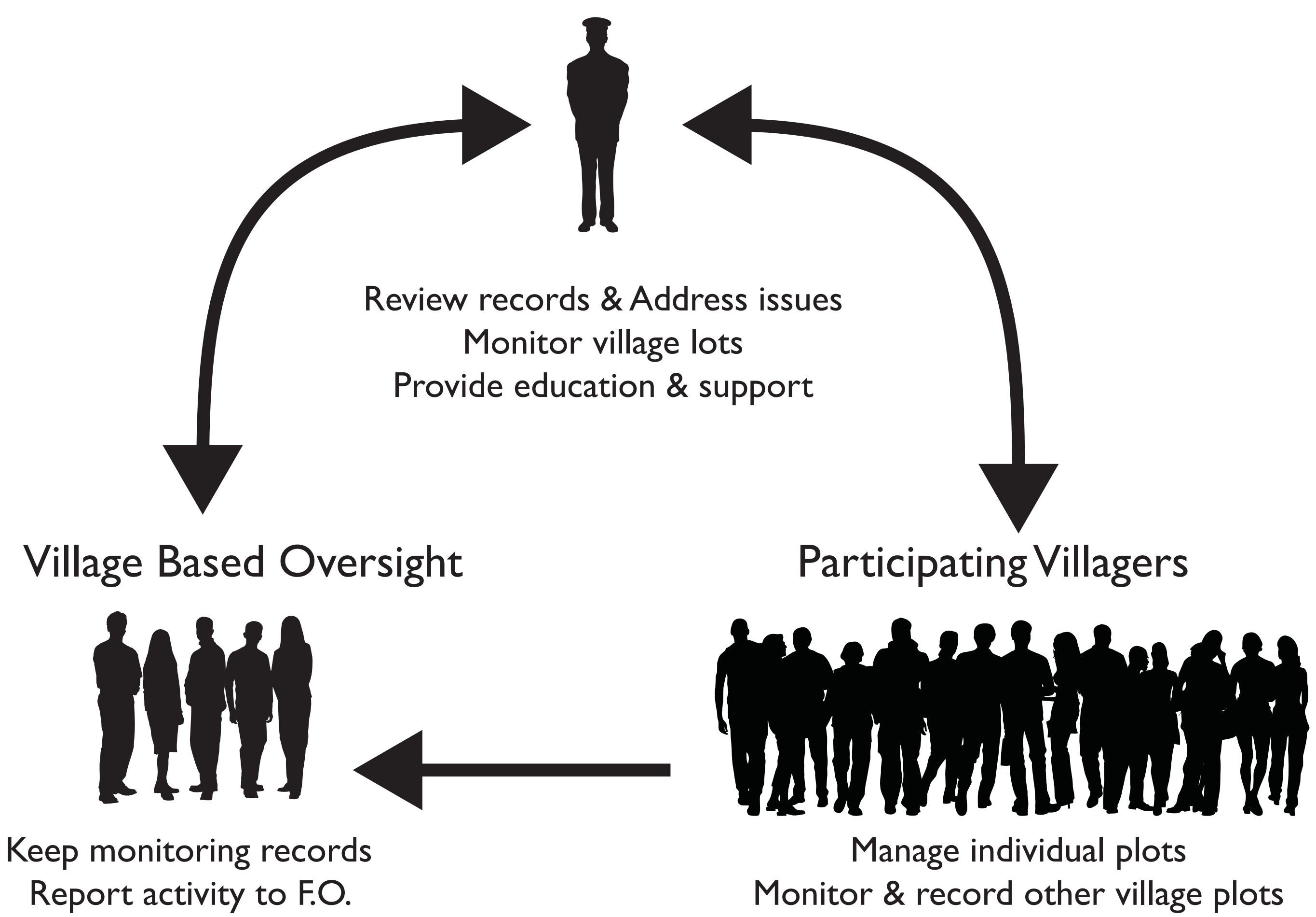




Fuelwood Reserves

System Structure:

Fuelwood production will be managed through an adaptation of Joint Forest Management on a smaller scale, dealing with individualized woodlots for each participant. In this structure benefits will be directly distributed to the lot holders rather than through a village committee.



Fuel Produced:

On a 3 year harvest a significant amount of fuelwood can be produced, when paired with other initiatives like fuel-efficient stoves or rice husks, this can have a direct impact over the life of the projections on the lack of fuel resources as they currently stand.

Wood per Ha:
48.75 Metric Tonnes

Household Needs:
3,486Kg/Year

Fuel Supplied per cycle at maximum land conversion:

	Ha		
	49.35	2401.85 Mt	689
	90.39	4406.51 Mt	1264

Financial Support:

By creating a range of financial means to provide for the changes in these scenarios it will be possible to lessen the risk to wary and risk-averse villagers to provide the opportunity to participate without the financial burden.

Subsidies:

Subsidized lost crop revenues during years 2 and 3 of the fuelwood production cycle.

Incentives:

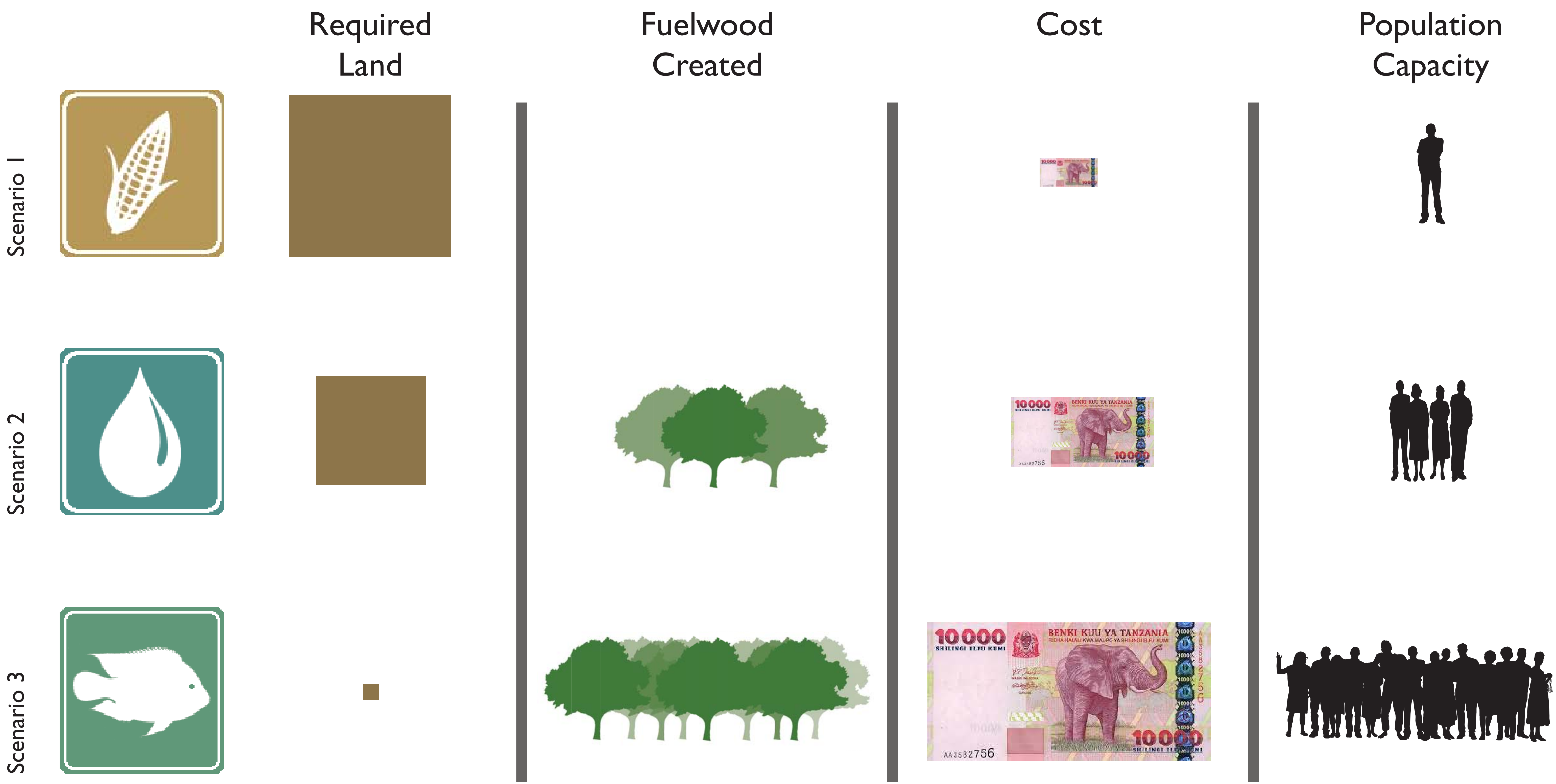
Incentive payments for participating in monitoring activities and adhering to JFM participation conditions.

Micro-Finance:

Creation of a finance group solely to back the newly implemented agricultural technology

Scenario Comparison

System Overview



Current Shamba System

2033: Capacity reached

Development plans in the village center around a rough grid, but do not show any discernible planning past that point. Houses are spaced and clustered in an inefficient manner decreasing the potential output of the land they use for subsistence. Our projection shows the organic infill of houses and shamba land relative to the current level per household in 2013. Approaching 2033, the plan indicates that very little area is left for possible expansion.

Projected Plan at 2033

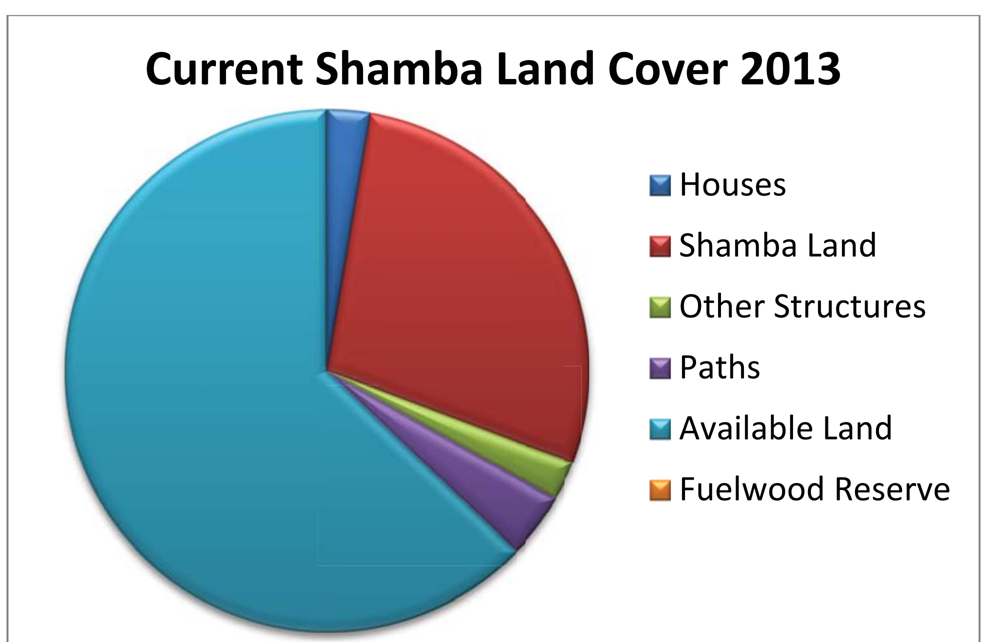
Projections

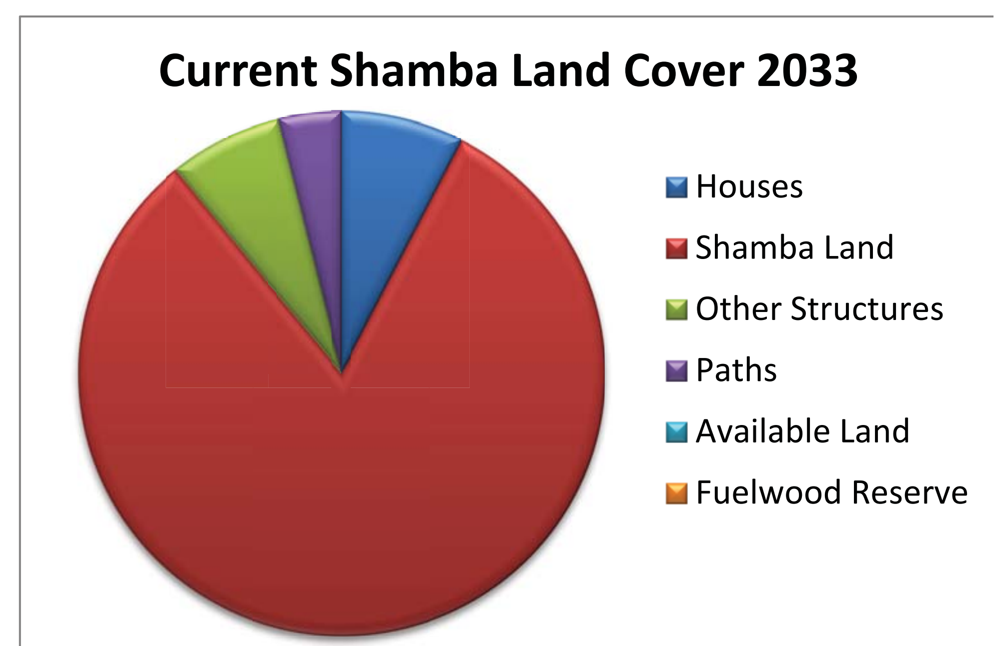
Land Coverage Of Current Growth Pattern and Shamba

Year	Population	House	Other Structures	Paths	Shamba (Ha)	Shamba Size	Available Land	Fuelwood Reserve Created (Ha)	Fuelwood Reserve Remaining
2013	3256	2.6%	2.4%	4.0%	48.0	28.1%	62.9%	0	0%
2023	5668	4.5%	4.2%	4.0%	83.5	49.0%	38.3%	0	0%
2033	9867	7.8%	7.3%	4.0%	145.3	85.2%	-4.4%	0	0%

*Population growth at 5.7% annually

Green = Available Land, Orange = Decreasing Fuelwood Reserve, Red = No Land Available





Drip Irrigation Systems

Introduction

Projections:

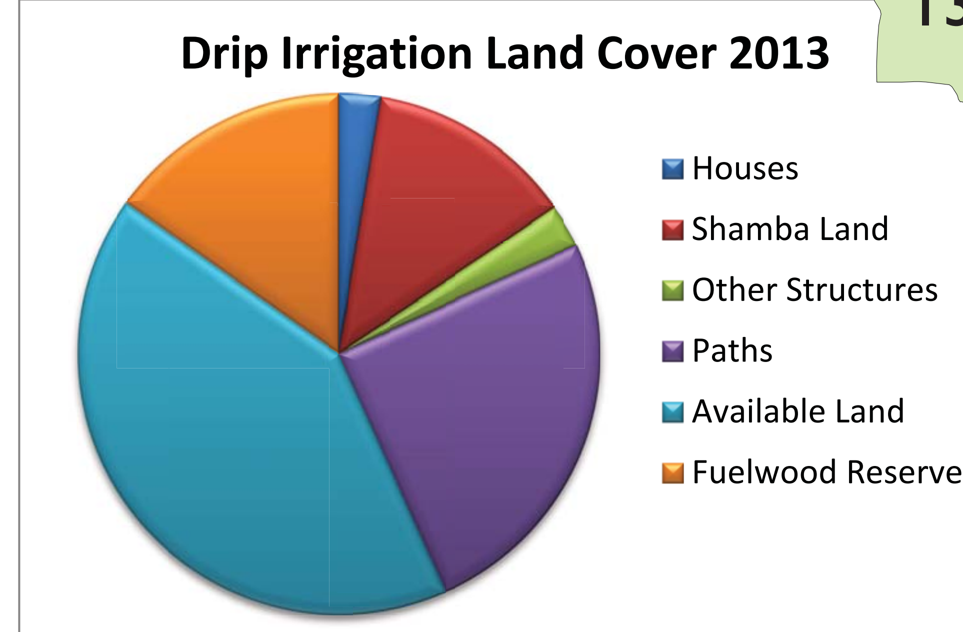
Drip irrigation requires 46% of land at current shamba production to meet the same capacity. Projecting population growth with this system sees available land at the current allocation reached in 15 years at 2028. Past that point the newly formed fuelwood reserves from the conversion of the remaining 54% of shamba allocation would be depleted to accomodate more housing and shamba allocations less the area given to fuelwood before 2028. These reserves would be depleted in 2039 where population growth will utilize all available land in Kisawasawa.

Land Coverage Drip Irrigation and ROW Regulations

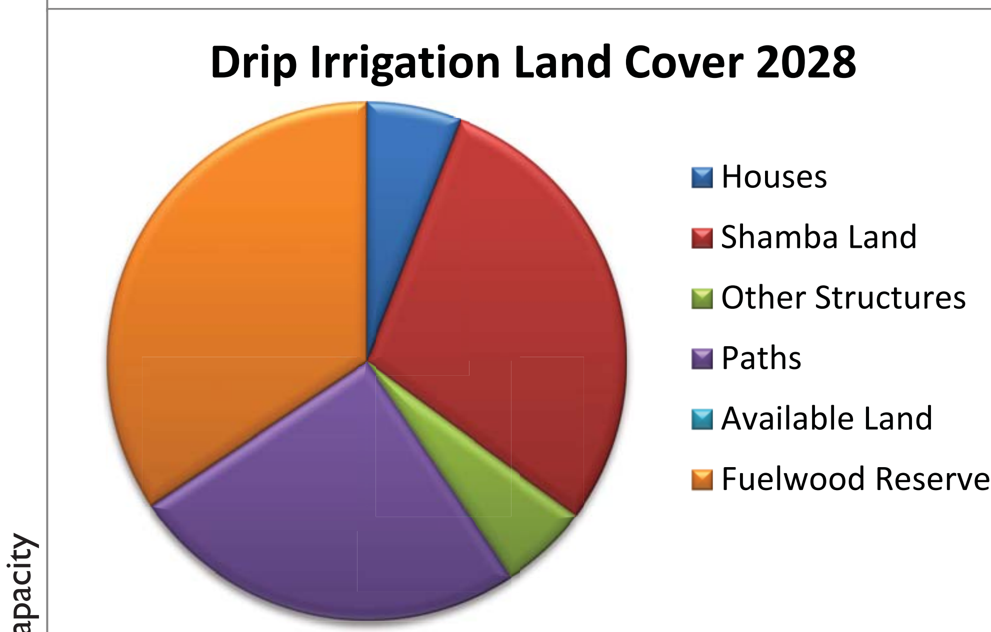
Year	Population	House	Other Structures	Paths	Shamba (Ha)	Shamba Size	Available Land	Fuelwood Reserve Created (Ha)	Fuelwood Reserve Remaining
2013	3256	2.6%	2.4%	25.2%	22.1	12.9%	41.6%	25.9	100.0%
2023	5668	4.5%	4.2%	25.2%	38.4	22.5%	17.1%	45.1	100.0%
2028	7478	5.9%	5.5%	25.2%	50.7	29.7%	-1.3%	59.5	96.3%
2033	9867	7.8%	7.3%	25.2%	66.9	39.2%	-20.4%	36.2	60.8%
2039	13760	11%	10.2%	25.2%	93.3	54.7%	-34.6%	-1.8	-3.0%

*Population growth at 5.7% annually

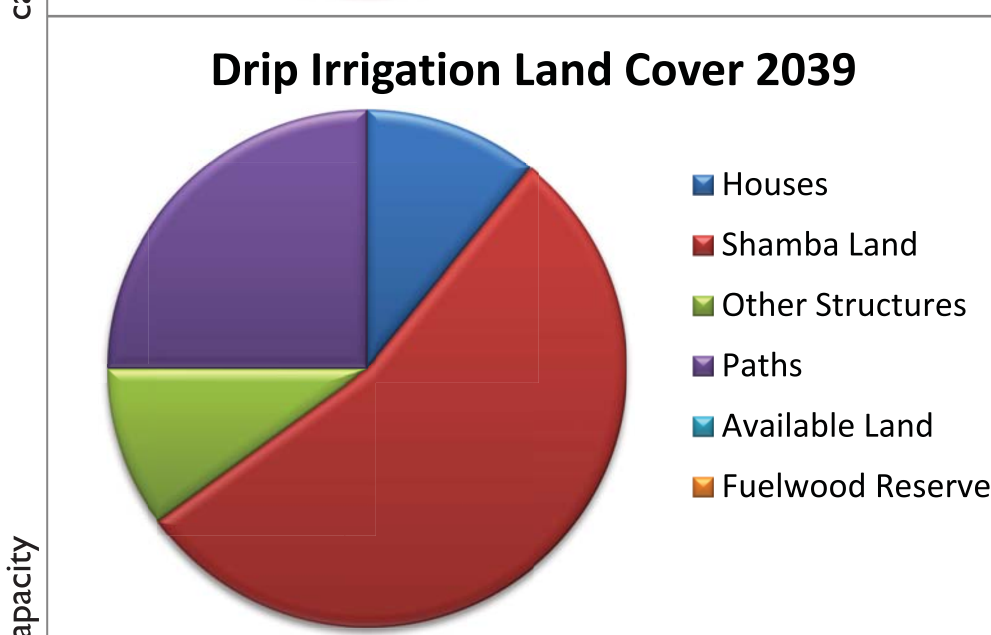
Green = Available Land, Orange = Decreasing Fuelwood Reserve, Red = No Land Available



Projected land use at available land capacity



Projected land use total village land capacity



Design A: Community Based

- Fuelwood land is centralized in each block area within the village.
- Expansion of housing and shamba land will overtake fuelwood reserve around the edges first, moving towards the center of the fuelwood plot.

Design B: Individual Based

- Land is organized into a modular lot unit creating rows of houses, drip irrigation systems and fuelwood reserve.
- Expansion of housing and shamba land will overtake the fuelwood reserve section of each lot, creating a new pedestrian alley between houses

Design A: Community Based

2028: Capacity reached

Key Design Aspects:

Design A is focused on a centralized creation of fuelwood plots. This provides simple access to more people while allowing easier communal management. Housing is located against the forest edge creating a strip of houses lining the forest reserve. This provides the houses with shade and a backdrop for privacy. Shamba land is placed against the pedestrian road, creating a walkway against the houses for neighborly interaction while also allowing for the crops to receive full sunlight for a longer period of time.

At 2028, capacity is reached at the current ratio and all growth moving forward will begin to deplete the pooled forest reserves pictured here.

25m 50m 100m

Projected Plan at 2028

Focus area at 2028

25m 50m

-Other Structures -Houses -Shamba -Trees

Birds-eye view indicating spacial orientation of shamba land, houses and fuelwood reserve from the road

Spatial characteristics between shamba land and houses

Design A: Community Based

2033: Forest reserve impact

Key Design Aspects:

As fuelwood reserves are depleted, houses and shambas will infill this new space. Forests will be cut along the edges, creating new housing layers similar to that seen in 2028 while maintaining a centralized fuelwood reserve. This pattern will continue where new houses will eat into the converted land, creating alternating strips of houses and shambas until all land is decreased in 2039. As this progresses the older strips will lose their shade and forest buffer, being at that point left in an open setting.

25m 50m 100m

Projected Plan at 2033

-Other Structures -Houses -Shamba -Trees

Focus area at 2033

25m 50m

Birds Eye View indicating spacial orientation of shamba land, houses, and fuelwood reserve from the road

Spatial characteristics between shamba land and houses

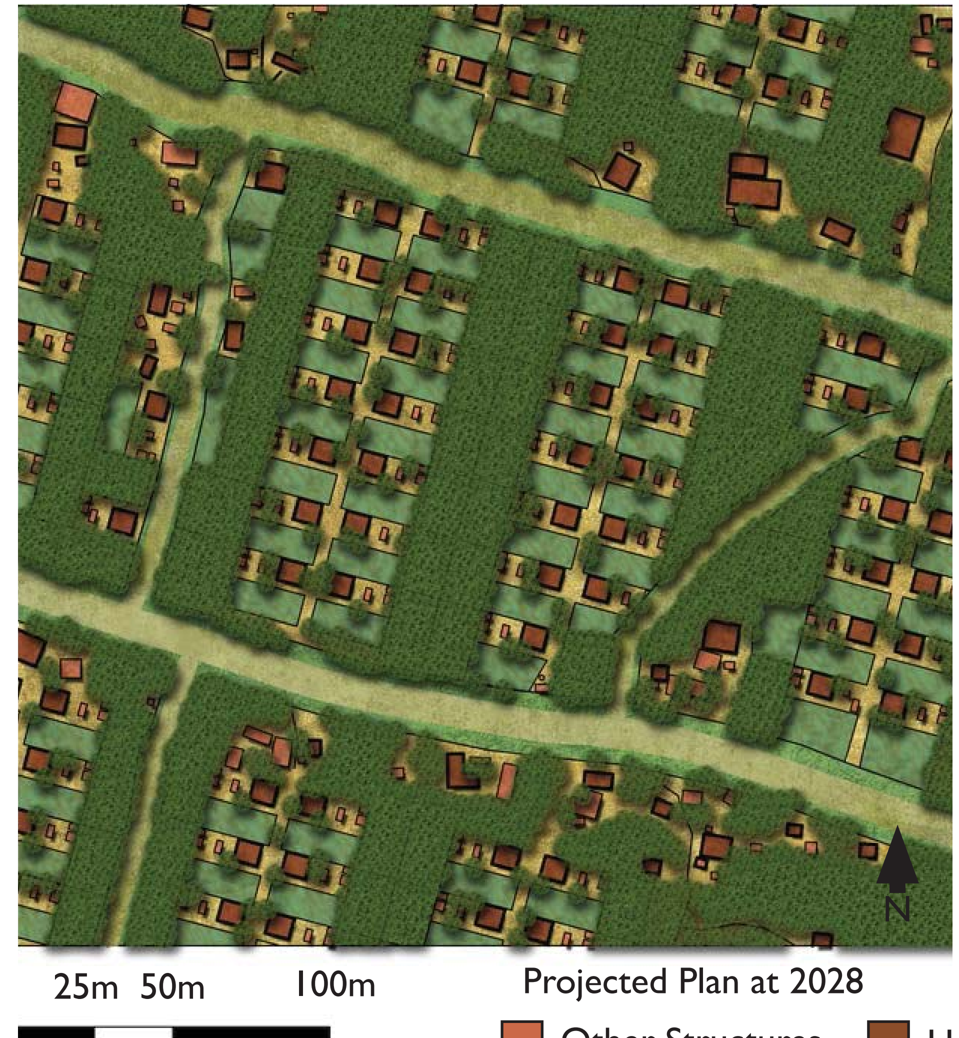
Design B: Individual Based

2028: Capacity reached

Key Design Aspects:

Design B utilizes a modular lot system that includes housing, shamba, fuelwood reserve, and all other structures. Each household is now responsible for their own fuelwood plot, which is placed in the rear of the unit, and together they form a forested alley between each row. Shambas provide a buffer between each house but also open air outdoor space for interaction with neighbors. New alleys are formed at the face of these units, providing access and interaction for the community.

Past this point depletion of fuelwood reserves will begin and the planning behind these forested alleyways will become apparent.



Projected Plan at 2028

-Other Structures -Houses -Shamba -Trees

Focus area at 2028

Birds Eye View indicating spacial orientation of drip irrigation land, houses, and fuelwood reserve from the road

Spatial characteristics between drip irrigation land and houses

Design B: Individual Based

2033: Forest reserve impact

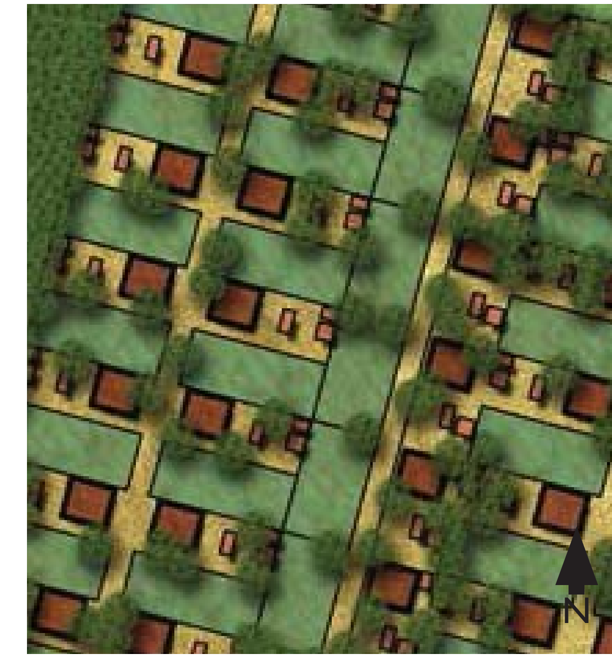
Key Design Aspects:

As further development occurs, another modular housing unit will being to replace the forest sections of the original housing plots. These forest alleys will now be converted into another pedestrian walkway with houses on one side and shamba on the other. This pattern will continue until 2039 where the conversion of the forest into housing alleys and the entire structure of Kisawasawa into a formal grid will be complete.

25m 50m 100m

Projected Plan at 2033

Focus area at 2033



25m 50m

-Other Structures -Houses -Shamba -Trees

Birds Eye View indicating spacial orientation of drip irrigation land, houses and fuelwood reserve from the road

Spatial characteristics between drip irrigation land and houses

Aquaponics Systems

Introduction

Projections

Implementing aquaponics as a substitute for current production will decrease the land needed by 99%, heavily increasing the land converted to fuelwood reserves in this model. While available land will be depleted by 2028, the amount of fuelwood reserve to be converted to residential area after that is 80% more than Scenario 2. Keeping growth constant, Kisawasawa in Scenario 3 would still have 42% of its fuelwood reserve available to accomodate for population growth past at the end of the study in 2053.

Land Coverage Aquaponics and ROW Regulations

Year	Population	House	Other Structures	Paths	Shamba (Ha)	Shamba Size	Available Land	Fuelwood Reserve (Ha)	Fuelwood Reserve Remaining
2013	3256	2.6%	2.4%	25.2%	0.5	0.3%	41.6%	47.5	100.0%
2023	5668	4.5%	4.2%	25.2%	0.8	0.5%	17.7%	82.7	100.0%
2028	7478	5.9%	5.5%	25.2%	1.1	0.6%	-1.3%	109.1	98.0%
2033	9867	7.8%	7.3%	25.2%	1.5	0.9%	-3.9%	100.3	93.8%
2043	17176	13.6%	12.7%	25.2%	2.5	1.5%	-15.7%	80.1	74.9%
2053	29901	23.7%	22.1%	25.2%	4.4	2.6%	-36.3%	45.0	42.1%

*Population growth at 5.7% annually

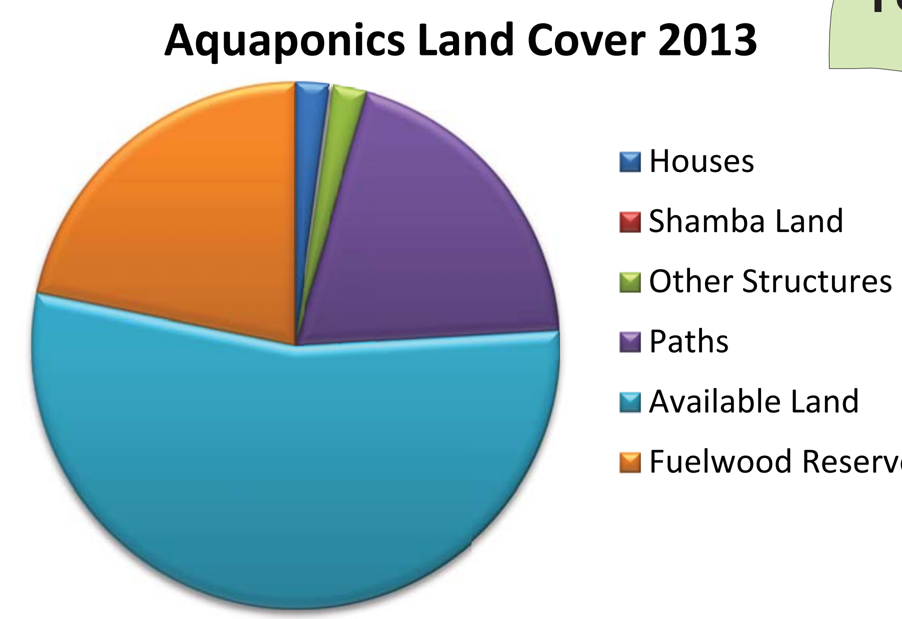
Green = Available Land, Orange = Decreasing Fuelwood Reserve, Red = No Land Available

Design A: Family Groups

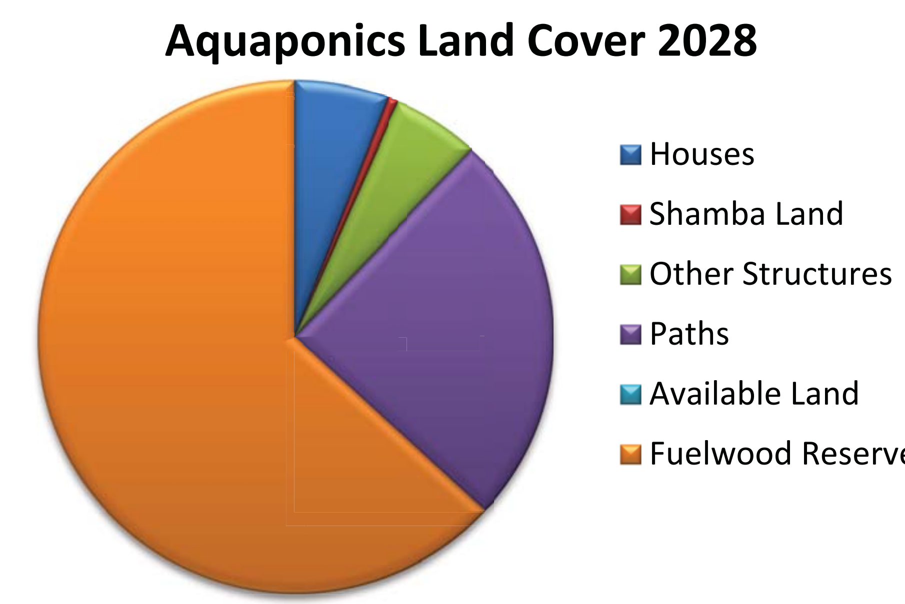
- Housing growth is clustered based on current family housing patterns in the valley
- Fuelwood reserves are substantial areas at the center of the street pattern that provide various design and planning functions

Design B: Pedestrian Road & Modular Units

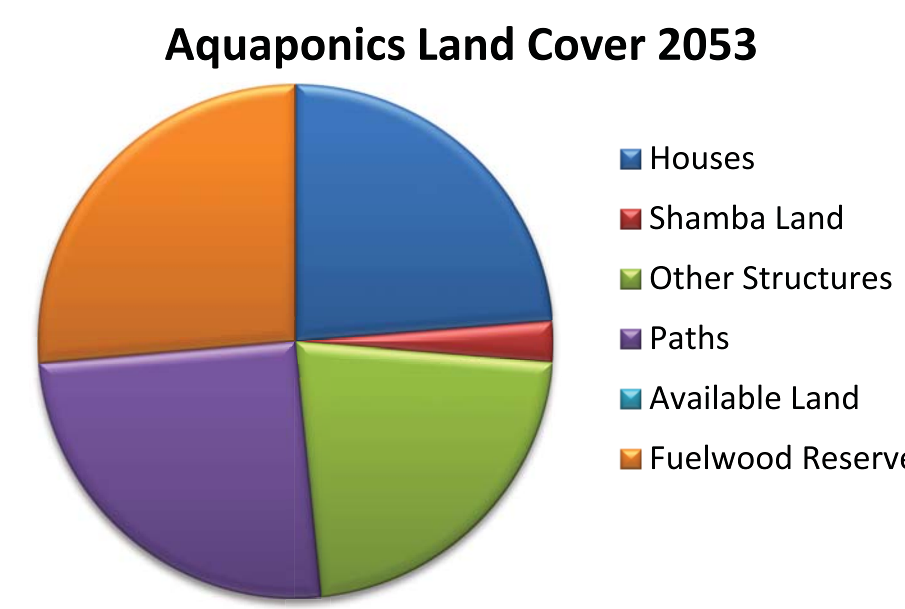
- Housing units are organized in pairs to share the responsibility of the aquaponics system
- Fuelwood reserves are generalized and provide separation from other housing units and roads
- A new pedestrian road is implemented running East-West

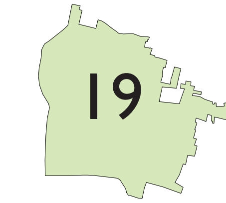


Projected land use at available land capacity



Projected land use at 40 year study





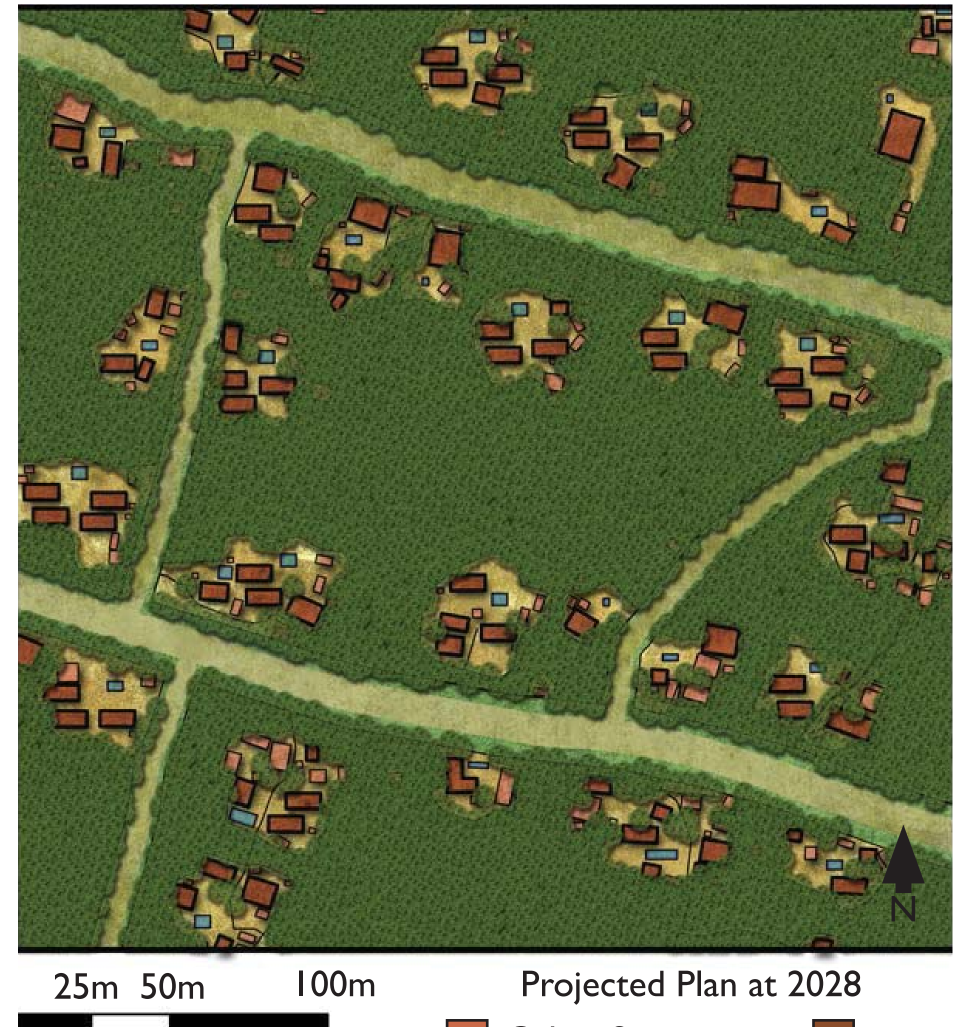
Design A: Family Groups

2028: Capacity reached

Key Design Aspects:

Design A continues the trend of family housing groups but with more attention to the needs of housing structures and communal space. Structural spread is minimized, and the forest provides a roadway buffer and focused access along with a spacial enclosure around the cluster's common grounds. Inside, latrines are relegated at the back of the houses and the kitchens on the eastern edge to carry smoke away. The aquaponics structure is centered in the most sunlit area, providing optimal growth conditions while close to a group of houses making oversight and care shared between the group.

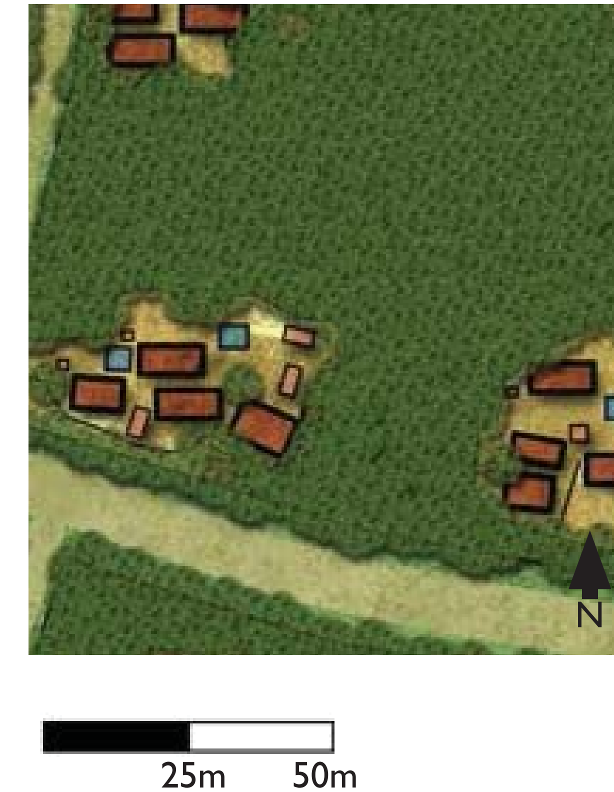
In 2028, fuelwood reserve is still vast, and ample room for accommodation remains to develop more land into family housing groups without encroaching on existing houses.



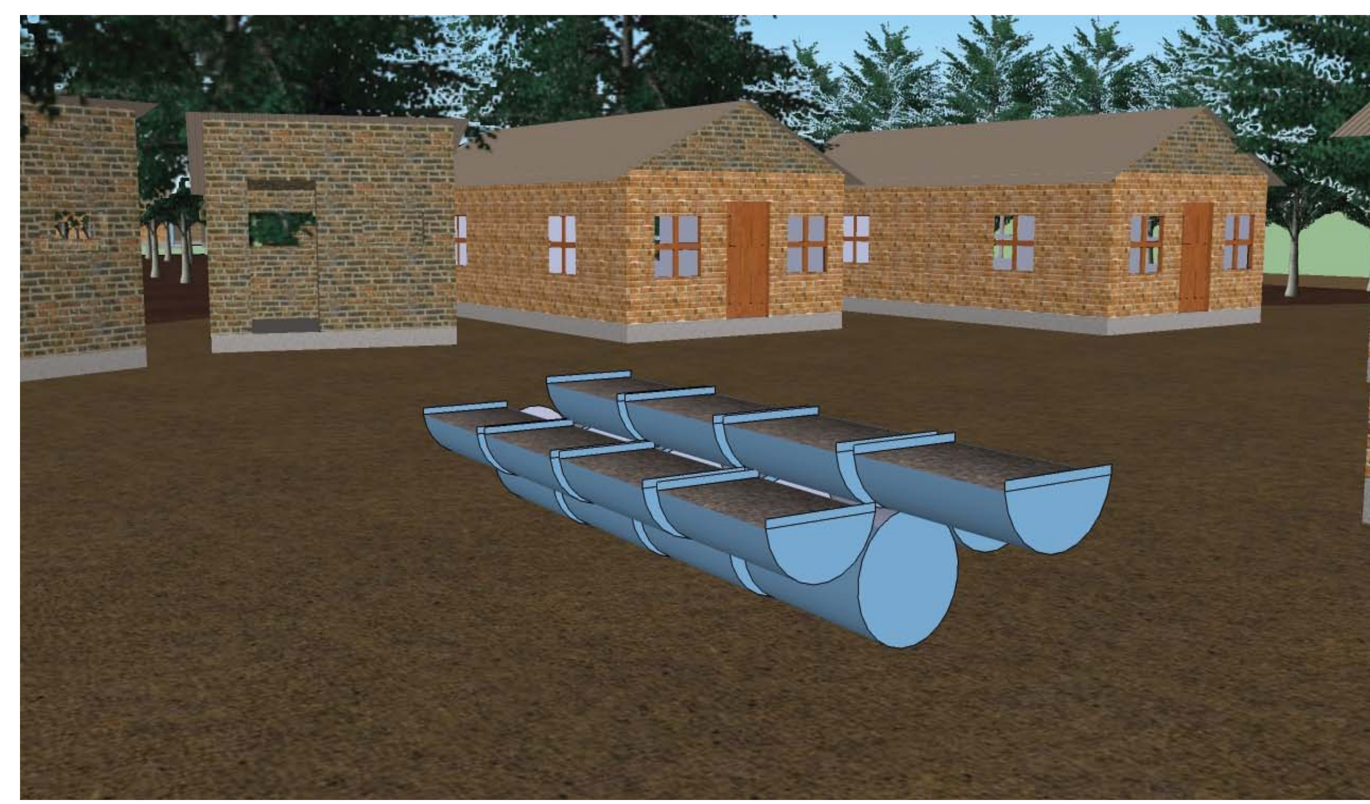
Projected Plan at 2028

-Other Structures -Houses -Aquaponics -Trees

Focus area at 2028



Birds Eye View indicating spacial orientation of aquaponics, houses, and fuelwood reserve from the road



Spatial characteristics between aquaponics and houses

Design A: Family Groups

2053: End of study

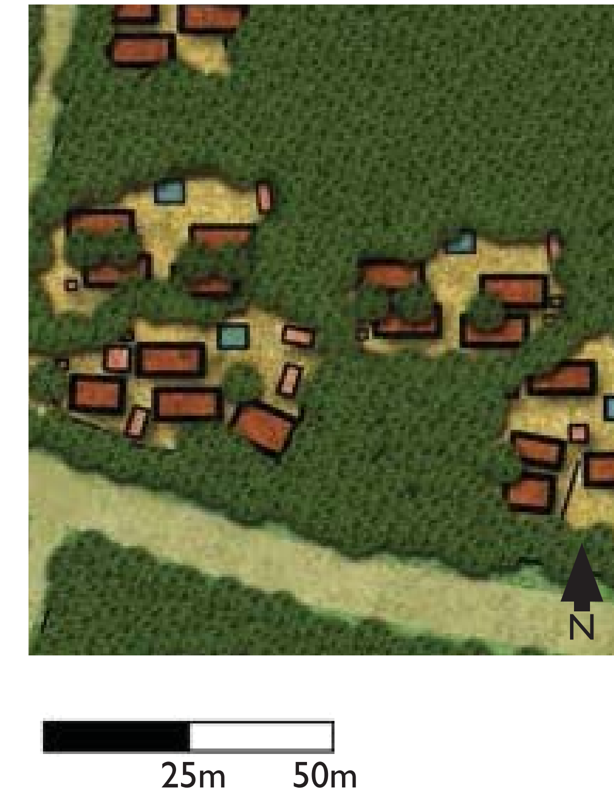
Key Design Aspects:

As population continues to rise fuelwood reserve will first be developed focusing on the edges to provide easy access to the road. Past that, the housing groups will fill in from the back of already established groups, furthering the forest opening pattern and allowing for the expansion of family groups to accomodate new family growth. In 2053, 58% of the forest reserves will remain, leaving plenty of buffer space between houses, along with the ability to still maintain fuelwood resources for village populations.

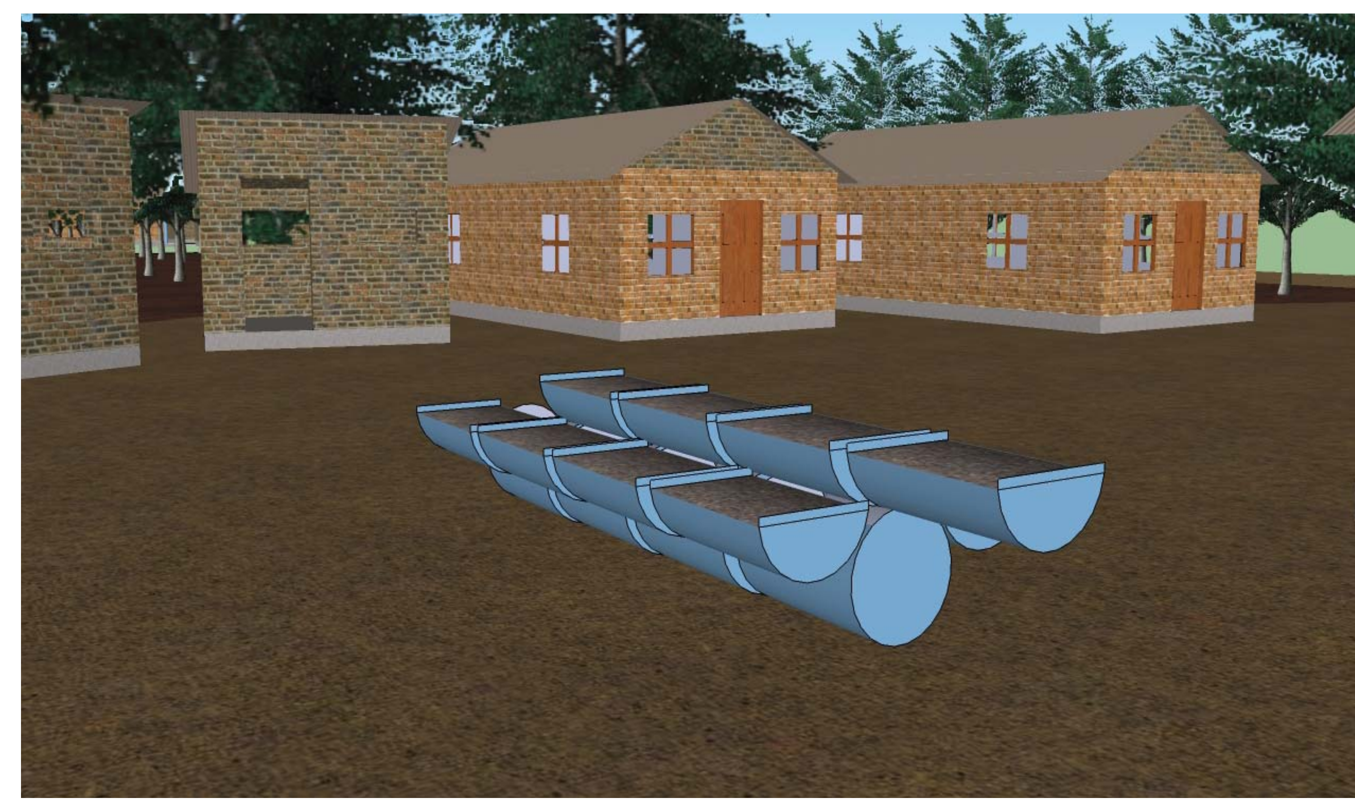
Projected Plan at 2053

-Other Structures -Houses -Aquaponics -Trees

Focus area at 2053



Birds Eye View indicating spacial orientation of aquaponics houses, and fuelwood reserve from the road



Spatial characteristics of the communal area in the rear of the houses where the aquaponic system is featured

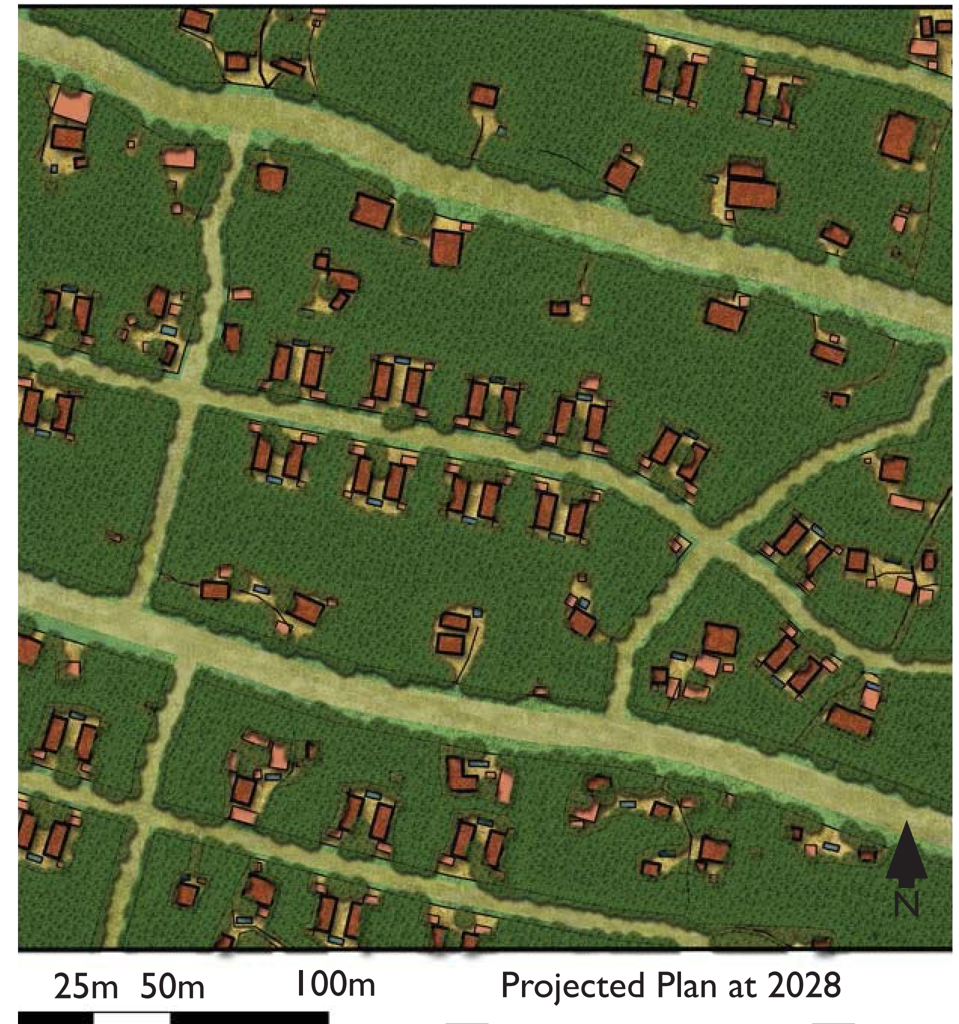
Design B: Road & Modular Unit

2028: Capacity reached

Key Design Aspects:

Design B implements pedestrian roads running east-west through existing blocks and develops a modular housing unit featuring 2 homes and a shared aquaponic system. The modular units are placed adjacent to each other with the kitchens and houses on the road front to facilitate typical social interaction between units and with passers by. In the rear the aquaponics unit has maximum sun exposure and is protected from the road front, while the forest creates a buffer and enclosure around the unit providing shade and privacy. By creating a new pedestrian road, the fast and dangerous vehicle and motorcycle traffic is not an issue, increasing the attractiveness of the design.

At 2028 when available land is met, there is still plenty of room for residential development while still accommodating for the vehicle road conditions and privacy of residents.



Projected Plan at 2028

Focus area at 2028

-Other Structures -Houses -Aquaponics -Trees

Birds Eye View indicating spacial orientation of aquaponics, houses, and fuelwood reserve from the road

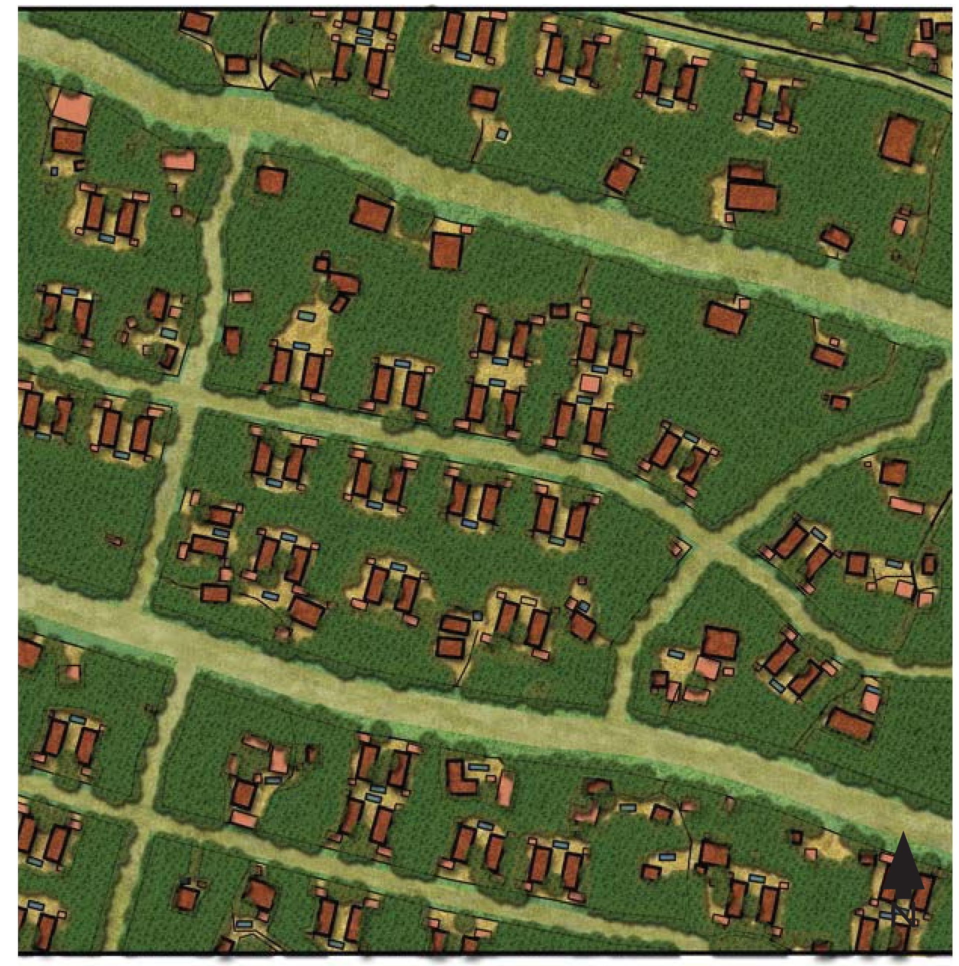
Spatial characteristics between aquaponics and houses

Design B: Road & Modular Unit

2053: End of study

Key Design Aspects:

Population in 2053 shows that housing modules begin to infiltrate the established housing areas and fill in along the main road after filling the new pedestrian paths. Modules being to back up against each other to create a larger community space and shared aquaponics system between 4 houses instead of 2. With a remaining forest cover of 42% there is fuelwood reserve available which allows the continued buffering and spatial characteristics of the housing modules to remain even with the increased housing density.



25m 50m 100m

Projected Plan at 2053

-Other Structures -Houses -Aquaponics -Trees

Focus area at 2053

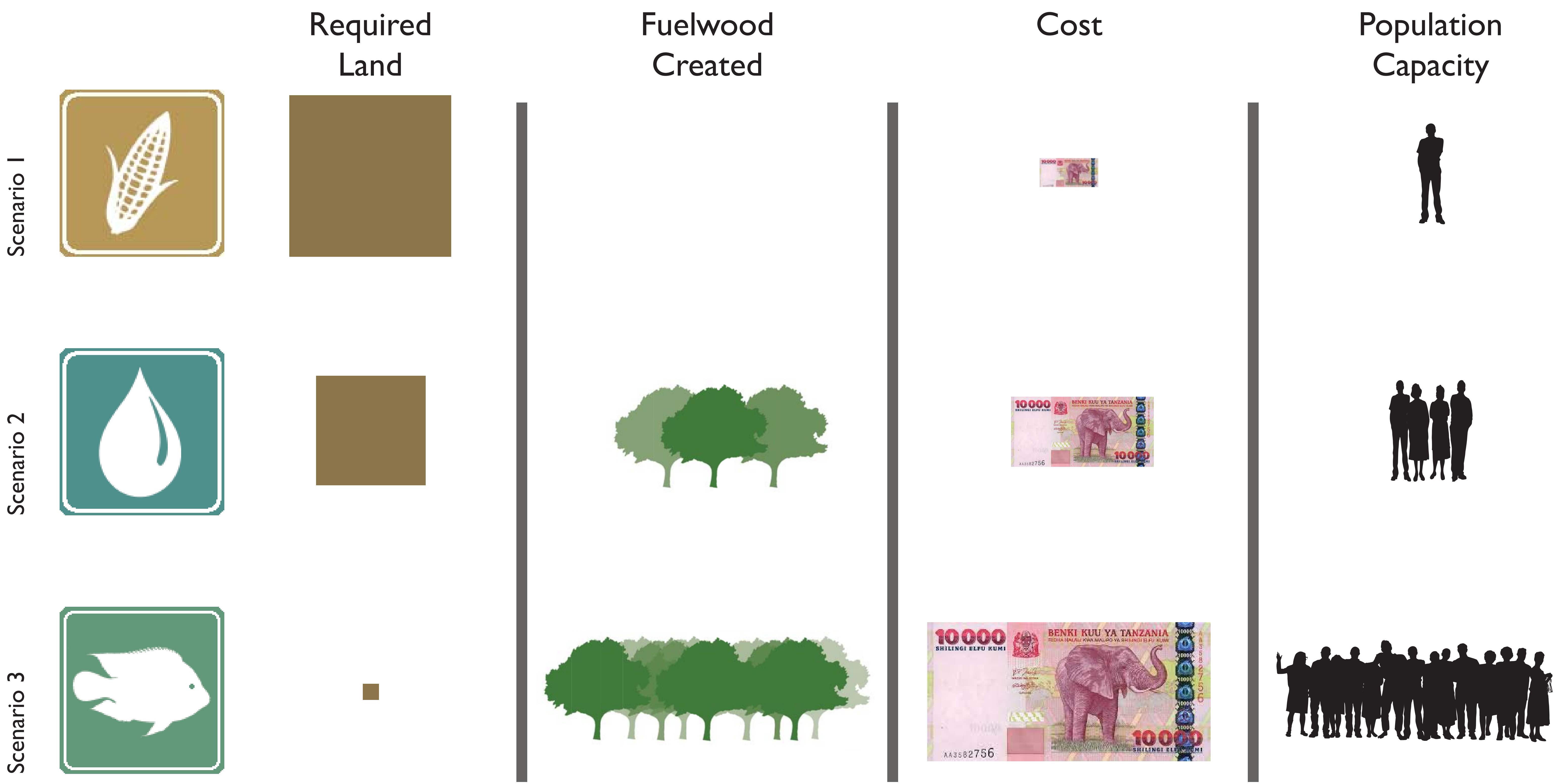
25m 50m

Birds Eye View indicating spacial orientation of shamba land, houses and fuelwood reserve from the road

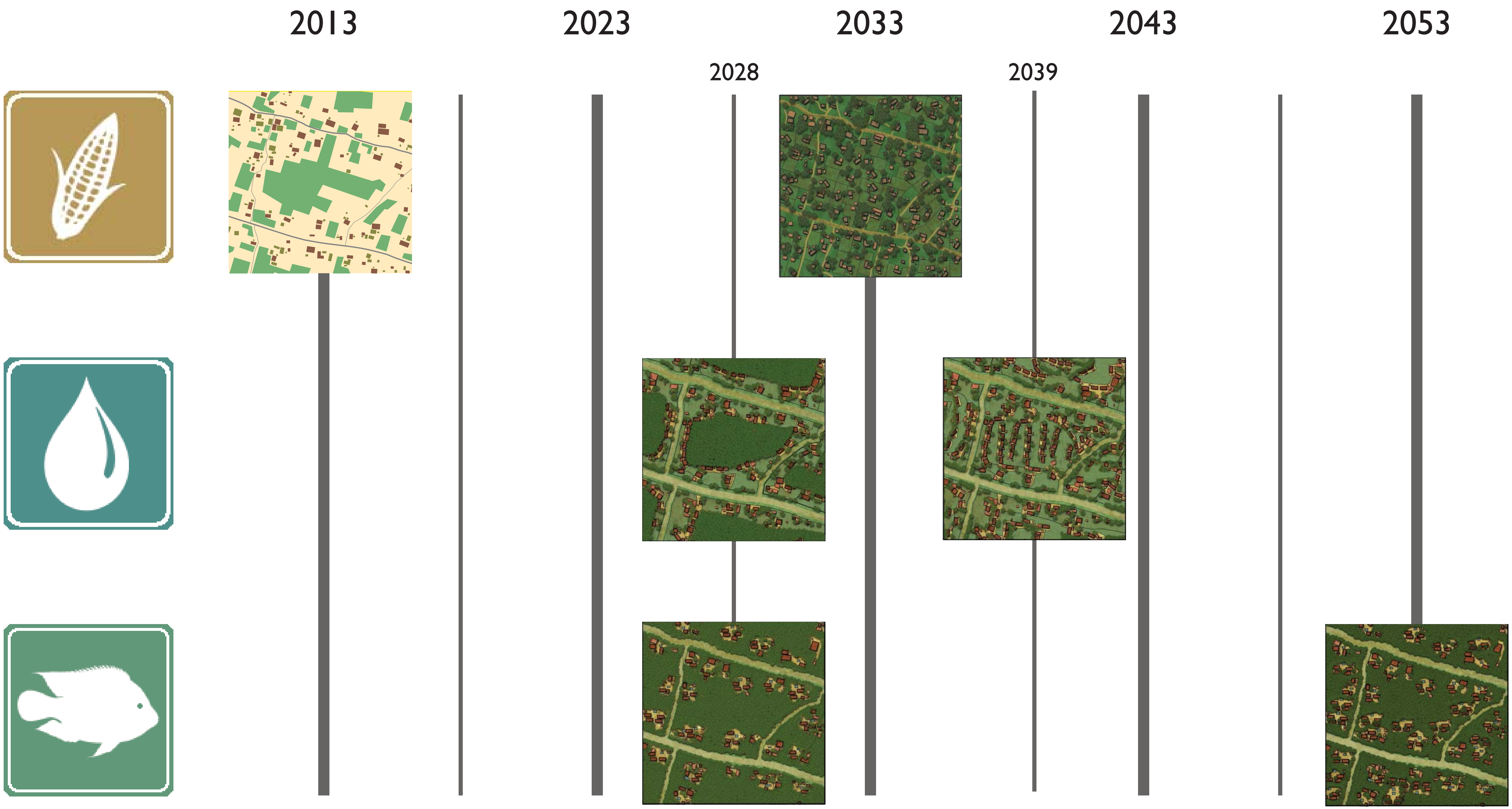
Perspective of the interface between the housing units and the new pedestrian road

Scenario Comparison

System Overview



Scenario Timeline



Implications

Future Implications:

The modeling of population growth on Kisawasawa has shown the implications that the future holds in regards to the ability to support what will be a drastically increasing population. If nothing else, bringing to light this information will allow for the implications to be realized and the areas of need to be addressed.

Feasibility:

Each of the scenarios employed a way to increase agricultural production but with an associated cost. As these may be means to help change livelihoods in the Kilombero valley, denoting the feasibility of one of these systems to actually be implemented on a household basis is necessary. Below are listed price estimates to upgrade existing shamba production per household based on the land ratio used throughout the scenarios modeled. Upkeep costs were not calculated into these estimates, but Aquaponics will require significant additional maintenance expenditures whereas drip irrigation does not.

Drip Irrigation: 140,000Tshs/Household

Aquaponics: 270,000Tshs/Household

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