Water Scarcity and the Solution of Sand Dams

Kenya is a water stressed country. Any cursory examination of the global literature on water indicates that Kenya is in the same category as countries of the Sahel, Pakistan, Iran, and Iraq. There simply is not enough to go around, and what does comes must be used wisely and well. That water is not used wisely or well is a statement of global importance. Water is likely to lead to more and more intense conflicts than oil (Postel 1992). At the same time water is a decentralized resource and requires a wide number of local solutions rather than a large scale solution.

When most of us think about water use personal consumption comes first. In Kenya, for developed country visitors, clean drinking water is a primary concern. We buy bottled water guaranteed free of the intestinal parasites and bacteria that cause unaccustomed folks so much tribulation. We can do this because we have the resources to buy water almost wherever we go. Humans need about three or four liters of water a day for direct personal consumption. This amounts to about 2 cubic meters of water a year. Country wide Kenya has less than 1000 cubic meters per person, but this is far more than a person needs. The problem is that direct personal consumption is a small fraction of the total really needed. More water is used for cooking, personal hygiene, dish washing, clothes washing and general cleaning of the household. Yet even this amount pales compared to industrial needs and industrial needs are secondary to the primary need for water to grow crops. Irrigation accounts for 70% of global water demand, ignoring the free gift from rain fed agriculture (Postel 1999). Water correlates directly to food production. Without water agriculture becomes impossible and food is unavailable.

Kenya is a complex country with regard to water. It has a number of highland areas, each small in relation to the total area of the country, that are rich with water because of their ability to attract the rain. These are the Kenya highlands, places surrounding Mt. Kenya, the Aberdare range, the Mau Escarpment, the Cherangani Hills, Mt Elgon, and a few smaller ranges that reach high enough to influence the formation of clouds. From these water rich points rivers flow out to the surrounding countryside eventually leading to the dry regions that cover 75% of the total land area. In most of these areas agriculture is impossible. The amount of water reaching them does not permit irrigation, and even if it did the soils are too salty to permit long term use. It is only in the floodplains of the lower Tana River, coming from Mt. Kenya and the Aberdares, that irrigation was significant enough for a people called the Pokomo to develop a culture around it. Elsewhere Kenya has mostly rainfed agriculture or pastoralism.

This paper deals with one of the areas in Kenya that lies between the water rich lands of the highlands and the water poor lands that dominate the country. It is the land of the Kamba speaking people in the counties of Machakos, Makueni and Kitui. Here the land is hilly, with the highest points reaching nearly 2000 meters, often steep, and commonly dry. Rainfall patterns in this region that lies between 0 and 3 degrees south latitude and 37 and 39 degree east longitude are complex yet often insufficient to produce crops. Because of its location the intertropical convergence zone, the equatorial phenomenon that produces weather in the tropics, passes over the region twice a year, giving two rainy seasons. The long rains occur in March, April and into May. The short rains last from October to early December. However these two 60 day periods of rain are inconsistent, occasionally fail completely, and

sometimes do not last long enough to allow key crops to complete their growth cycle. As a result the region has a chronic food deficit, only broken in the rare good season when rains permit growth of maize.

The region is not as consistent as painted in the paragraph above. The topography slopes from high points in Machakos and north-western Makueni, lowers toward Kitui to the north and gradually drops in elevation and gets correspondingly drier as you move south and east toward Kenya's Indian Ocean coast. The upper regions receive 800 to 1200mm of rainfall per year on average while the lowest areas of Kitui and Makueni receive less than 500mm annually. Generally maize requires 600mm of rainfall in one season to guarantee a crop. Only in the hilltops of the upper region in normal or above average seasons are rainfalls consistently sufficient. Yet the Kamba people throughout this region persist in planting maize in hope that they will catch a sufficient rainy season.

That they try is readily apparent to those who tour the area. However this has not always been the case. To understand this requires a bit of historical information. Although Machakos lacks the extensive highlands found to its north and west, it was the first land the British saw in the days just after the Mombasa to Kampala Railway was completed. By 1900 some British settlers began selecting land in the highlands of Machakos for growing coffee and other crops (reference needed). Though the area was limited in extent, this had the impact of moving Kamba people in the area downhill and onto steeper landscapes. By the 1950s this settlement combined with a growing population caused notable deforestation and erosion. In response the British colonial administration began mandating the making of terraces on steeper slopes. This practice was done but not without some pushback from local residents who resented imperial orders. In 1963 Kenya became independent and the idea of making terraces was forgotten for a time. In the next two decades Machakos District, which included Makueni at that time, was known for having some of the worst erosion in Kenya. This unwanted notoriety was not lost on the people of the district and some began on their own to seek solutions to this problem. A lot of this was documented in the book by Mary Tilley called "More People, Less Erosion" published in 1994.

Water and erosion are found together since most of the erosion here is related to rain and runoff. Storms when they do come are often short and very heavy, leading to a quick buildup of water on the surface of bare and clay sealed soils and with the steep slopes runs off quickly. Soil loss can be catastrophic for already worked land, resulting in depletion of topsoil or in the worst cases the entire field. At the same time you lose soil you also lose the water. People noted that springs that once were perennial began going dry, sometime failing to recharge even during the rainy season. As the population rose a higher and higher percentage of people spent more of their day simply fetching water. Working up to three hours per day to collect water was not unusual for many. Often this meant walking downhill to seasonally dry streams, digging holes in the sand of the streambed and extracting what water remained in the sand. This practice continues to this day in many streams and rivers of the three counties.

In the 1970's a young man working with the National Christian Council of Kenya (NCCK) named Joshua Mukusya was very aware of these dual problems. He grew up near Kola, a town near the present

border between Machakos and Makueni Counties. As a young boy he was often sent down the hill to fetch water in whatever container he could find then carry it back up hill to his mother. If he spilled a drop on the way he received a vivid reminder of why you should be careful. As he grew he wondered why it is that rain falls on his house and runs off downhill, then later he has to run downhill to fetch it. Why not catch it before it runs away (Mukusya, personal communication July 2011).

Not much later in NCCK Joshua worked with a man named Ndunda who had built dams with the British in the 1950's. Joshua visited some of these dams with Ndunda and saw that many were filled with sediment, primarily sand. When you dug in the sand behind the dam water was there even in the driest of seasons. The thought came to him at the time, why not build dams intentionally to capture the sand. Within NCCK he had seen literature about sub-surface dams used to slow subsurface flow of water to allow pastoralists to water their animals without the need to dig deeply and lift the water to the animal. The subsurface dams enabled the animals to drink the water directly. This would not work in Machakos very well since the river had too steep a slope and the amount of sand trapped would be minimal. By constructing a dam between 1 and 3 meters high they could capture more sand and therefore more water in the pore space between the sand grains. Joshua envisioned this happening, but to do this took more than simply a vision.

To build a dam on a stream in Kenya required permission from the regional government and you had to apply for permission to do this. Individuals could not apply; the application had to come from a registered group. It so happened that Joshua and his wife Rhoda were involved with a group of people in discussions about what they could do to better their own situation and the status of the community. In 1978 these 6 families started a self-help group they called Utooni Development Group. They paid their dues, developed a group charter, selected a president, vice-president, treasurer and secretary and where duly granted official status by the Kenyan government. They had a number of things that they wanted to do, among them were planting trees, digging terraces to stop erosion, building guesthouses, improving agriculture, and above all improving the water situation. So the first thing they pursued was the building of the first intentional sand dam in the area.

The Utooni Development Group's success at supplying water for itself did not immediately lead to repetition. That came with time and many meetings to understand the dynamics of change in the communities. The reality is that the social context of a community, how people relate to each other, to neighboring communities and the government is more important than the technology of building a dam. Dams are community structures that meet a basic need. It is the community that must decide they want and need one. Joshua recognized that without the community structure in place and solidly grounded a dam alone would not solve the problems they faced. The organizational structure was essential before the dam was built. The Utooni Development Organization, which is a direct descendent of the Utooni Development Group, recognizes this reality, spending much of its time and energy encouraging formation of community self help groups and addressing water and agricultural issues. Help is not just a sand dam. Help comes in developing the community to the point where members can help themselves.

The community process of building a sand dam

At this point it is best to take time to describe the general structure of a sand dam and the process communities must follow to build one. Sand dams are of necessity bulky structures. They stand across a stream holding a considerable volume of water and sand depending on the height of the dam and the degree of slope in the stream. In order to hold fast they must anchor to the bedrock of the stream. Across the entire width of the stream loose bedding material must be cleared to bedrock, including the sand of the dam, which may involve digging through a lot of soil to anchor the wings of the dam. Most dams measure between 1 and 4 meters in height above bedrock and are highly variable in width. Figure 1 shows a typical dam, this one built by the Kitandi Fruit Tree Growers Self Help Group. In general the dams are just less than 2 meters thick at their base and sloping on their downhill side toward the top which is about a meter thick. The uphill side is vertical. The dam in Figure 1 contains approximately 90 cubic meters of cement, sand, water and rock. They are anchored to bedrock using 18mm rebar that extends from the rock to just below the top of the dam. Forms are made after the rebar is secured and the process of building the dam begins.

Figure 1: This sand dam was built in 2009 by the Kitandi Fruit Tree Growers SHG on the Kaiti River in Makueni County. It was extended one year later to reach its present height. It has a 17.9 meter spillway and holds nearly 11,000 cubic meters of sand and 4,000 cubic meters of water when saturated. Note the strong stand of napier grass on the right stream bank. It is also planted as cuttings on the left bank. (Photo by the author, July 2013)

Building a sand dam is the responsibility of a community self help group, though they receive assistance from UDO in the form of dam engineering, dam construction supervision, cement and rebar. UDO will not come until the community meets certain criteria and this is undoubtedly the most important aspect of the project. Development in rural areas succeeds or fails based on the degree of ownership by the local community. Joshua Mukusya and the Utooni Development Group recognized early on that giving a sand dam to a community group leads to failure of the group. Give away development does not work. Instead UDO insists that the self help groups participate fully in a series of projects complementary to the dam. It harkens back to Joshua Mukusya's initial work with his own self help group; tree planting, erosion control and alternative crops.

Trees are essential in this region. They provide stability for the soil, organic material, food, timber from dry area adapted species, shade, property demarcation, firewood, medicine, fodder and much more. Many farmers have discovered that vegetable crops grow better under trees. Fruit trees bring profits in years that little else grows. Since trees are perennial plants they do not require cultivation that can lead to soil erosion. UDO requires that each self help group they partner with develop their own tree nursery and start planting trees on land of community members. This is not an insignificant program. One man in the Makuta Mwea SHG, Patrick Musyimi, has planted over 10,000 trees and he is still working at his forest. UDO encourages fruit trees, especially mango, avocado, guava, papaya, oranges, mulberry and if appropriate the vine passion fruit. Trees of note promoted by Utooni include *Moringa oleifera, Melia volkensii, Croton megalocarpus, Grevillea robusta, Warburgia ugandensis, Prunus africanum, Azadirachta indica* and many others. To UDO trees are an investment in the future of the community they want everyone to make.

Soil erosion remains a concern in the district. Terraces are now widely accepted and UDO deserves some of the credit for this. Before a community group can build a sand dam they must first build two terraces on each side of the dam. UDO engineers and the community members map out the terraces along the contour upstream from the dam site. These terraces must be one meter deep and the full length of the sand dam reservoir, which in some cases stretches for over 500 meters. In this case it would mean building 2 kilometers of terrace for one sand dam. Since it takes 1 person day to construct 2 meters of terrace, the community group commits to 1000 working days of terrace construction. The terraces serve two purposes; they limit erosion from the side of the stream into the sand reservoir and they allow water to sink into the ground contributing to the sand dams rather than washing off the surface and lowering the impact of the sand dam.

The third item self help groups must do is creating a seed bank for drought tolerant varieties. Most seed companies do not carry these crop types because the market is limited. These three districts suffer episodic drought as explained earlier, yet most farmers insist on planting maize, a crop that is not drought resistant. UDO promotes a number of crops in this category including lab-lab bean[1], pigeon pea, millet and sorghum. This program is considered the hardest sell to community groups of all UDO's

[1] Dolichos lablab, or Lablab purpureaus is a native African legume the produces a crop in very dry conditions. It is resistant to insect attack due to its cyanide content, but this is easily leached out with water. http://en.wikipedia.org/wiki/Lablab and http://www.eattheweeds.com/hyacinth-bean-purple-protein-and-more-2/

activities. Growing maize is what Kamba people do. Maize produces abundantly in the right conditions and effectively limits losses to birds, which can be a problem. However it also frequently fails, as most did in the long rains of 2013. By having drought resistant crops people are assured of a harvest even if it is not their preferred dietary choice. UDO's hope is that acceptance and use of these crops will increase steadily through time increasing food security in the area.

When these three items are accounted for the work on a sand dam begins, but the community's participation does not end. They are responsible for labor, sand, rock and water for construction. Often these must be gathered in advance. Sand is easily available in the rivers here and is usually collected within a few meters of the dam itself. Stones on the other hand must be broken from bedrock. In these three Kenyan Counties most of the bedrock and smaller cobbles are gneiss, a type of metamorphosed granite that is quite hard and resistant to erosion. There are some rocks that are nearly pure quartz, but these are comparatively rare. Gneiss rock is layered and will break in sheets if pounded the right way. Sheets of gneiss are not what you want in a sand dam. More desirable are larger stone pieces varying from 1 to 25 kilos in size. These are commonly not readily available so must be broken off exposed pieces of bedrock, which takes considerable effort with a sledge hammer. In some areas water for building a dam is hard to come by. Groups building their first dam often struggle with this since dams must be built during the dry season. One dam being constructed by a group in Kitui, supervised by a Kenyan NGO there called SASOL, had to carry the water by donkey cart or donkey back 17 kms to the site. Most self help groups do not have this problem, but carrying water a few hundred meters is not unusual. Often groups will work in advance of the main construction day to gather all these materials so that when cement mixing begins nothing is missing.

A Community Extravaganza

Building a dam is a genuine community effort. In this UDO and SASOL are perhaps unique. On larger dams it is a site unlike you will see almost anywhere. In July 2013 a group called the Kaiti River Self Help Group built a dam on the Kaiti River about 5 kilometers from the town of Wote in Makueni District. All the rock was gathered, sand was available and piled on the riverbed, water was readily accessible, the bedrock was clear and the rebar was set. UDO brought in three other self help groups from the surrounding area, calling the event a dam building extravaganza. Each group had well over 50 people involved. Work started at the dam site at 7:30am. It is a 45 minute drive to the dam from the UDO office in Kola staff and they all came including their CEO Kevin Muneene. There were a few minutes of opening speeches and then the Field Manager for this part of Makueni divided the groups into four sections of the dam, divided the staff including the author and 5 students, and sent all off to start building. The day was cool and the task was simple; each group to mix 90 bags of cement with 270 wheelbarrows of sand, add water, add this to the already in place forms, add rocks and watch it grow. And grow it did, organically, rapidly and joyously as shown in Figure 2. People knew what to do, shovels flashed, wheelbarrows were loaded, strong backed young men brought 50kg sacks of cement, mixing happened and concrete flew. It was a dance with purpose. Each person contributed what they could. Yes, some rested on shovels while others worked, but even strong boys get tired and need to lean, so girls and woman, with smaller quick strokes filled in the gaps.


Figure 2: Mixing cement at the Kaiti River Self Help Group's sand dam extravaganza, July 2013.

Pour, mix, stir, throw was the pattern. You take 3 wheelbarrows of sand, add one of cement, four people start mixing, then throw the pile one step closer to the dam and repeat with new sand and cement. The next group of 4 or 5 does the same mixing with shovels and moves the pile again, and a final group stirs and builds a bigger pile to get a mountain of mix. Finally someone says enough and a volcanic crater is dug in the center of the 20 cement bag pile and women add water. The men wait until the "leader" says go and 10 people with shovels start mixing. There is an art to it, slowly turning the outside of the crater into the center mixing in the water until you end up with a moist pile, not quite yet wet enough. Then the young men take over, these are guys with strong legs and backs, not an ounce of fat anywhere, who take this heavy mix and stir while women add more water. When the slurry is ready they throw it to the next pile of prepared concrete to a point along the dam where it is then thrown over the forms and into the dam at the direction of the dam artisan. This artisan is in charge of placing the concrete and rock. They are also the ones who built the forms with SHG member assistance. When the concrete has reached the right thickness, they direct the throwers to put the concrete in a new spot, so they either throw further, or a team of men and women throw the concrete further down the line to the next tossing point. Meanwhile the artisan yells for stones, big ones and middle sized ones at first. She (or he) receives the stone from a continuous line of folks handing medium stones from one to another until they reach the dam. Great big stones are carried by the biggest guys and hoisted to the artisan with grunts and assistance. The artisan moves down the line following the concrete throwers and the dam gets built. Throughout the process 50 plus people have been involved, each doing the

things needed at that particular time. Some things happen continuously, like mixing sand and cement, but others, like throwing the concrete and moving stones only happen as needed. Watching 300 people doing all these tasks nearly simultaneously with no job foreman is a wonder to behold. At the end of 7 hours the extravaganza had mixed 280 bags of cement and added a full meter of height to a 90 meter section of the dam. All that remained was to finish the top and add the 17 meters of wings, 8+ at each end, to the dam.

Figure 3: Adding rock to the cement mix near the end of the work day on the Kaiti River sand dam.

The Kaiti River dam is the longest and second largest that UDO has designed to date. It will serve around 6,000 near the town of Wote. While constructing the dam a number of trucks with water tanks and tractors pulling tanks came to the river and filled them with water. They sell the water for 3/= for a 20 liter jerry can. The dam itself has a 90 meter spillway and sand will fill the flat bottom of the river an additional 1.5 meters above its present level. A survey by UDO showed that sand would back up in the river to a distance of over a kilometer. This means the dam will store an additional 75,000 cubic meters of sand. On average sand has 35% pore space meaning that potentially 26,000 cubic meters of water will be stored. If all this water were sold at the Wote price it would have a value of just less than 4 million Kenya Shilling, or about $45,000 US. The dam cost, while not finalized by the UDO accountants, is something less than $25,000 US including all cement, rebar, barbed wire, forms, surveying and

engineering time and time the UDO staff spent building the dam. The return on investment is as high as any development project can hope to achieve.

Conclusion

Sand dams are a solution that will work well in a number of regions. Communities are building them in Tanzania and Mozambique under the leadership of the Mennonite Central Committee. Potentially they can work anywhere that bedrock is close to the surface, river bed slope is less than 3% and the streams carry a good bed load of sand. It also takes a community that recognizes its need to build a sand dam. They do not work without community participation. When these conditions are met then impact on a community is striking. The amount of time women and children spend collecting water drops, food security improves, nutrition levels rise and school attendance increases (Mutiso 2002). The Utooni Development Organization has now built over 1500 dams. SASOL in Kitui District has built another 1,000. Both groups are still expanding. Sand dams are not a fast and simple fix, rather they are a durable community based solution to the every widening problem of water .

References

Mutiso, G.C.K. 2002. “Kitui Sand Dams: Social and Economic Impacts.” *Muticon*. Nairobi, Kenya.

Postel, Sandra. 1992. Last Oasis: Facing Water Scarcity. Worldwatch Institute.

Postel, Sandra. 1999. Pillar of Sand: Can the Irrigation Miracle Last. Worldwatch Institute.