# A Report on the Impact of Sand Dams on Community Development in Semi-Arid Agricultural Areas in Kenya

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South and east of Nairobi lays a land of steep hills divided by complex valleys filled with the farms of the Kamba people. As you travel from the town of Machakos, a major commercial and government center, toward Makueni the landscape alternates between dry lowlands and steep green hills rising as much as 600 meters above the valley floors. In one of these semi-arid valleys the Mkuta Mwea Community Group of has embarked on a major project of transformation. Our guide on this occasion was the chairman of the Mkuta Mwea Community Group, Justin, who started us at his farm. The farm lies on a terraced hillside, not very steep by the standards of the area, and looks rich. Tomatoes, French beans, Swiss chard, green peppers, sikuma wiki (a relative of collard greens), maize and green gram grew vigorously. When asked how well he was doing on sales of his crops Justin laughed and said he now has people driving all the way to his farm to buy fresh vegetables. Considering that the road is steep, narrow, dirt and primarily suited to 4-wheel drive vehicles this is quite a feat. Apparently he cleared over 100,000 Kenya shillings (about $1200) in the last four months on the tomatoes alone. His entire farm is less than one hectare.

The key to Justin's success and that of the Mkuta Mwea Community Group is water. The area around Mkuta Mwea receives between 500 and 800 mm of rainfall each year. The variability is primarily one of elevation. There is another aspect of variability that makes the average numbers relatively meaningless. The Ukambani region comprising the districts of Mwingi, Kitui, Machakos and Makueni lies between 1° and 2° south of the equator within the belt of bimodal rainfall. The rainy seasons are relatively short, intense, and often unreliable. Failure of any given rainy season ranges between 3 and 7 in 10, with lower elevations seeing the higher failure rate (Tiffan et al, 1994). In the last decade drought became even more frequent (Lasage et al. 2008). The National Oceanographic and Atmospheric Administration shows that this region of Kenya has suffered between 300 and 600 weeks of extreme drought since 1981 and much of that in the last decade, with greater drought lengths in lower elevation areas (NOAA 2011). Even though the road to Mkuta Mwea passes through higher elevation areas the site of wilted maize stalks gave evidence to the failed rains of March-May 2011. The rains that did fall in this latest rainy season were short and heavy, leading to high runoff. Catching this water and holding it for steady use directly leads to Justin's production of tomatoes. To catch the rain the Mkuta Mwea Community Group worked with the Utooni Development Organization (UDO) to build a series of seven sands dams on their local river between 2005 and 2009. A sand dam is a relatively simple structure. The UDO engineers work with the community to find locations on the river suitable for a dam. A dam needs direct attachment to bed rock. The engineers find places where the bedrock is close to the surface and pinches the stream bed width. The mobile stream bed material is removed and reinforcing bars (rebar) are cemented into the bedrock. Forms are then constructed to make a cement wall over a meter wide at the base and 1 to 3 meters tall. The community group is responsible for labor, rock, sand and water for the dam construction. UDO supplies the rebar, barbed wire for holding forms in place, cement bags and a skilled artisan to direct construction. Justin has one of these dams about 150 meters from his farm. Justin's dam stands about 3 meters tall from the lowest point on the downstream side. It is firmly attached to rock on either side, rising nearly two meters above the wide spillway. On the upstream side sand has filled in the stream bed to the lip of the dam itself. Facing upstream, on the left hand side of the dam, is a large hole dug in the sand.

This is filled with water to about 30 cm below the height of the dam. Justin and some neighboring farmers have fenced this hole with thorny shrubs and branches to prevent cattle, sheep, goats and donkeys from using this water. They have purchased a small gas-powered pump to lift water from the hole to the top end of their farms so they can use gravity to distribute the water as needed to their crops. They do not have to use the pump every day, but without this water it would be impossible to grow any crops at this time of year. With it, Justin and his neighbors have more than doubled their annual income and improved their own food supply. Even so, irrigation water is not the most important aspect of the sand dams. In the mid-1970s the Ukambani area of Kenya was noted for problems with deforestation, erosion and poor water supply. Even earlier the British in the colonial era noted severe problems in the region due to steep terrain, intense rainfall and poor landscape management especially with regard to hilltop forests. That some of these problems were induced by the British due to confiscation of the highest and best land for export crops like coffee was duly noted. This had the effect of pushing the Kamba downhill to more vulnerable landscapes. As population grew in the early period of independence more people experienced water shortages and land degradation. Their reaction to the colonial era attempts to impose erosion control measures led many of them to reject any recommendation for soil and water management (Tiffen et al 1994). The present CEO and co-founder of the Utooni Development Organization, Joshua Mukusya, felt these conditions personally and recognized that if something were to improve the situation it could not wait for outside help. He and his wife then teamed with 5 other couples to form the UDO. They decided that priority number one was the supply of clean water for household use. At the time the average household in the group spent a minimum of three hours per day collecting water of variable quality (Personal Communication, July 2011) Joshua had a key advisor, Ndunda, who worked with him at the National Christian Council of Kenya from 1975-1980 and had worked on sand dams during the colonial era to supply water (Maliti, n.d.). These dams were effective, but little used by the resident communities and the idea did not take hold. Joshua noted that the sand behind these old dams held a lot of fresh water, up to 40% by volume filling the pore space between the sand grains. This water did not evaporate like the water from open dams. Ndunda taught the newly formed Utooni Self Help Group (a precursor to UDO as well as a separate community group) how to build dams with the express purpose of filling them up with sand. Unlike sub-surface dams that only impede the below ground flow of water, the idea of a sand dam is to impound a greater volume of sand to increase the available water holding capacity of the stream bed. By this time in 1980 the Utooni Self Help Group was a government recognized community group with the right to petition to build structures like a dam. They got the permit and organized a community dam building effort, installing a 2 meter high dam in a stream near their homes. It was a near immediate success. Some time was needed for the dam to fill with sand, but it soon provided a year round source of clean water. Since that time the original dam has grown from 2 meters to nearly 6 meters in height with 4 additions. It supplies everyone in the community regardless of group membership and has served as the model for subsequent dam building efforts. Water collection time has dropped from an average of 3 hours to less than a half hour per day, a significant labor savings that enables a great deal of additional economic activity. By May of 2011 the Utooni Development Organization, with some outside funding from various organizations like Excellent Development, UK (Mandrell 2010), the Canadian Food Grains Bank and the Mennonite Central Committee, had constructed over 1400 dams in Machakos, Makueni and Kitui Districts and were expanding into Kajiado District to the South, among the Maasai (UDO 2011). Groups had also come from Tanzania and Mozambique to receive training and were expanding the dams into those countries. It is a technology that has proven itself, though simply having the technology alone is not enough to make this project a success. Developing a culturally relevant community dynamic and organizational structure to build the dams in an agro-ecological context is crucial. Without a functional, officially recognized and effective community organization the sand dam technology will not work. The foundation rests in the community not in the technology of the dam. UDO does not work with individuals, it only works with groups. These groups, like

Mkuta Mwea, must be officially registered with the government, requiring payment of a 1000 Kenya Shilling fee and an annual renewal. It must have a leadership team consisting of a chair, a vice chair, treasurer, and secretary to form an executive committee and have at least 30 members. Once this is in place UDO will do a study with the committee of the best place to locate a dam. Even at this point dam construction cannot begin. First the community group must prove itself by building two trenches on either side of the stream each one meter wide and one meter deep. These trenches on the Mkuta Mwea dam, where Justin has his irrigation pump, are each over 300 meters long and form bench terraces where erosion that could bring sediment into the dam is stopped. The labor commitment to build these terraces is significant. It takes one person using only a pick and shovel one day to do two meters of trench on average. Thus for the Mkuta Mwea dam it required 600 person days of labor. Also necessary before dam construction was the development of a tree nursery and a seed bank for crops appropriate to the climate of the area. Once these are ready UDO will supply the construction foreman, rebar, wire, forms and cement for the dam. The community supplies the rock, sand and water. The dam construction itself is part community celebration and another round of hard work. Joshua Mukusya is adamant that development has a cost. You cannot get something for nothing. The idea of giving a community a dam or a pump or a tree nursery will not work. In fact that is a fundamental problem of development whether it comes from multilateral, bilateral, government or non-government organizations. A gift does nothing to develop the managerial skills, local accountability and community ownership necessary to keep a project functioning in the long term (Mugambi and Kebreab, 2005). By insisting on the establishment of disciplined and internally accountable community groups prior to dam construction UDO has developed a system with a very high success rate that has become self propagating. The UDO team now has over 75 active community groups and a number of new groups on its waiting list for projects, including 5 in Kajiado. In Mkuta Mwea the basic water supply problem is solved. Now the quest is to pursue the best ways to use it. The number one use remains household water. The reduction in labor needed to collect it opens up a number of other opportunities. Watering animals is another major labor saving factor. Prior to the construction of the dams, families had to take their animals to the nearest water hole in the stream, or to a borehole site, often taking hours. This meant that animals were then grazing freely in a region of high human population density contributing to overgrazing and erosion (Tiffen et al,1994). With the dams farmers can take their animals once a day to a nearby stream, let them drink their fill, then take them back to a stall near the house and feed them using a cut and carry system. The fodder comes from the irrigated land along the stream that is lined with fodder crops like Napier grass, a superior fodder species. The manure is then mixed with excess fodder and crop residues and composted for application to agricultural land. Irrigation has not occurred as a regular activity in much of Ukambani in the past. There was no historic need during the pre-colonial period and little available water supply during the early years following independence. As such UDO has made a strong effort through its field officers to encourage development of irrigation strategies. Along the Mkuta Mwea stream many farmers have dug shallow holes for extracting water to irrigate above the trenches. Commonly water is carried in twenty liter containers and used to irrigate vegetables or fruit trees. Fruit trees include mango, avocado, guava, papaya and banana, all of which are used directly or sold through local markets. The size of these gardens varies depending on slope and available labor, but their contribution to household income is substantial especially if the male head of household lives at home. Not everyone in Mkuta Mwea can afford a pump. They cost between 28,000 and 32,000 Kenya Shillings ( $318 to $365). UDO supports a much simpler system developed in part by Jacob Stern, PhD. who works with them seconded by the Mennonite Central Committee. In this system Dr. Stern uses a standard 20 liter water container with a valve in the bottom to hold two tubes leading to two 15 meter lengths of drip irrigation pipe. This drip line has holes approximately 30cm apart along which you can plant a variety of crops. The total cost of the equipment is just over 900 shillings ($11). A number of these systems are now in operation. Dr. Stern estimates that with proper use a farmer growing tomatoes can pay the entire cost of the system in three months. Success does attract agencies with other strategies for development. Mkuta Mwea's dams attracted the attention of the United States Agency for International Development

(USAID). About a kilometer upstream from Justin's farm, the community group has installed a larger drip irrigation system completely paid for by USAID. This system uses a gas powered pump to raise water about 20 vertical meters to a 2000 liter holding tank. The tank is connected to a mainline pipe with a number of side drip irrigation lines, enough to supply water to an area of approximately 20 by 60 meters, or 0.12 hectares. Though no exact numbers on costs were available, we made a rough estimates that the system, pump included, cost about 100,000 shilling ($1200). The community group was organizing labor for the system and in the first four months they had already earned enough to cover the cost of the system, if they had been required to purchase it. USAID had given it for free. How this gift is treated once it suffers its first breakdown remains uncertain. One of the goals of UDO is to create sustainable communities in Ukambani and the next step after water supply is to encourage self-reliance in food production. Just having water in the sand dam area is not enough. Most crops are grown beyond the reach of 20 liter buckets or irrigation pumps. Here people must grow crops that are rain fed and the rains are unreliable. Thus there is a push to grow annual crops that are drought resistant like lab-lab bean, pigeon peas, sorghum, millet and deep rooted perennials. The difficulty of getting people to change their food preference priorities is one of UDO's chief concerns. People in Ukambani are dependent on maize, a water hungry crop. Persuading people to grow the other crops involves both an effort to supply seed and successfully adapt eating habits. The seed supply question is the reason UDO has implemented a seed bank requirement for the sand dams. This provides the community groups with a local seed supply under their own control. Monitoring the quality of this seed is one of the tasks of the UDO field officers. Getting community groups members to continuously plant and eat the alternative crops is perhaps the most difficult question UDO faces. We saw little evidence of widespread use of alternative crops in our observations of the sand dams. Justin continued taking us upstream to visit more dams. We had with us a Hach salinity meter designed to measure conductivity in water and translate that measurement into a total dissolved solids reading given in milligrams per liter (mg/l). Any time irrigation is practiced it is important to understand the salinity content to avoid problems with salinization over the long term. Our measurements varied along the stream bed, usually with a range of 300-600 mg/l, which are not too different from measurements of surface streams in the United States. This is not considered an immediate salinization threat, and given that above average rains will flush fields on occasion, in this area problems are not anticipated. One of the dams held water that was higher in salinity, rising to near 1600mg/l. This part of the stream had steeper walls and the sand was scarcely touched by water holes and most of these were used for animals. Usually humans cannot taste salinity at less than 500mg/l. The water held behind this dam did not taste right to local residents and they preferred getting drinking water from dams either downstream or upstream. This leads to an intriguing question; if the water behind dams upstream and downstream is less saline than this particular dam, where does the salinity originate? An average sand dam built by UDO is 2.5 meters high and has collected sand for 500 meters upstream. The average rise in the in stream saturated zone for the full 500 meters is 1.5 meters. If the average width is 20 meters, then storage capacity in this stretch of stream within the sand itself will be approximately 3000 cubic meters when fully saturated. In this state it is not isolated, but connected to the geology of the rocks and soil surrounding the sand. At Mkuta Mwea the land rises continuously above the stream sometimes with low slopes and other times relatively steep slopes. The saturated zone behind the dam leaks water into the ground on either side if it is not saturated. As this rock becomes saturated it will further back water uphill until the higher groundwater level finds another route around the dam (Hut et al, 2008). It is impossible to accurately state how much water is stored in the surrounding rock because every rock and soil strata touched will differ in its capacity to store water. A detailed geological survey is required to do this. Some of this rock will hold essentially no water, as you would expect for granite, which is found in parts of the area. Some could approach 30 percent, as you would expect for sandstone, which is a common rock in the valley. For the sake of argument we estimate that the average storage capacity of the surrounding rock is 10 percent. Also for the sake of argument let us say that after a number of years of maturity the impact on ground water extends 50 meters on each side and up to 2 meters high. (Because of the way water flows underground this is not an unreasonable conservative guess, but it is a speculative exercise not based on data.) As this rock becomes saturated it would hold around 10,000 cubic meters of water, more than 3 times the capacity of the sand in the dam. So when you extract water from the sand it is just as likely that the water replacing this extracted water comes from the surrounding rock as it is from the upstream sand. One particular test done on a dam just downstream from the little used dam gave us additional evidence that water is likely to come into the dam from the side even during the dry season. It was a dam that had a very long sand storage behind it and most of the holes tested for salinity were in the 200 to 600 mg/liter range. However, one dug at the mouth of a side stream entering from the left as we walked upstream, had salinity over 2,600 mg/liter. Just 80 meters upstream at the next hole the salinity dropped below the normal stream level to 150mg/liter. Fifty meters downstream the salinity level was just 450mg/liter. This strongly suggests that the side stream has both a small volume and very high salinity. It also means that it is important to test side stream entry points. Knowing both the rock type and land use on that side stream would improve our ability to determine how salinity fluctuates in the sand dams. One question that Joshua Mukusya gets frequently about sand dams relates their impact on those who live downstream. The concern is that a sand dam, or especially a series of sand dams, will restrict water supply for those living in areas even drier. The answer to this question makes good sense but is initially counterintuitive. Rainfall often comes in short but intense bursts. Runoff on barren land is rapid and the rise and fall in stream volume follows the same pattern. The trenches along side of the dams and the dams themselves serve to slow down the water giving more time for it to seep into the ground recharging the water table and filling the pore spaces both behind the dam itself and in the rock to the sides. This does reduce the water flowing downstream in the short term, though the amount is small. In Kitui District they have shown that dams impound only 1% to 3% of seasonal rainfall (Hut, 2008). However it also increases the amount of water retained upstream that will continuously work its way much more slowly downstream through the stream channel or through groundwater pathways. Older residents in both Machakos and Kitui, where sand dams installed by another Kenya NGO called SASOL are located, remember springs from their youth that subsequently dried up as population grew, agriculture intensified and deforestation increased. With the installation of the sand dams some of these springs have reappeared, some seasonally and some continuously (Mutiso, 2002). This anecdotal evidence indicates that the downstream impact of sand dams is strongly positive. Slowing water down does not decrease water availability; it prolongs its availability throughout a watershed. As this availability increases the impact on communities widens and spreads. If properly managed this water becomes the keystone of community self-reliance and sustainability. It certainly has started down that road in Mkuta Mwea and many other communities in the region.

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