Sand dams: Africa's answer to climate change?

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Abstract

In semi-arid regions of Africa, sand dam technology can make a significant contribution to mitigating the impacts of climate change by providing a low-cost solution to the problem of water conservation. Despite clear benefits, sand dams are used relatively little as they are very labour intensive, meaning a lack of effective community engagement can endanger project implementation and sustainability.

Excellent Development (ED) is a charity that integrates sand dams into a holistic community development model which addresses soil and water conservation and food production in line with the community's priorities, thereby enhancing sustainability.

In the areas where the charity works, the environment is degraded and water is scarce; people have very limited ability to generate income. ED's approach helps people harness the resource that is available to them, their own labour, and supports them in turning their commitment into positive change. With the charity's technical expertise facilitating the community to site and build their own dam, community ownership and thereby sustainability is greatly enhanced.

Sand dams are reinforced concrete walls built in seasonally dry riverbeds. Sandy areas which experience high siltation during water runoff are perfect. The dam traps the sand behind it and creates a sub-surface reservoir which will provide clean water year-round. Sand dams raise the water level both up- and downstream, revitalising the ecosystem, and enhancing income generation opportunities. Conservation priorities are further supported by establishing tree nurseries close to sand dam sites, enabling successful tree planting projects.

Sand dams and tree planting are two of the three key elements of ED's model: the third is land terracing. Used together these methods can benefit livelihoods in a way which doesn't compromise the environment, but strengthens it. The current pressure of climate change and threat of economic, social and environmental instability makes the implementation of such approaches to sustainability even more urgent.

Keywords: Sand dams, Africa, climate change, sustainable development

Introduction

Excellent Development (ED) is a UK charity that supports community groups in semi-arid areas of South-East Kenya to improve their water supply, food production, health and incomes through soil and water conservation. The charity integrates environmental and socio-economic priorities into its work, creating a development plan which is adapted to suit the particular stated needs of each community that is supported.

The range of strategies that may be utilised by the charity at each stage of a community's development is illustrated in Figure 1, representing the process by which environmental improvements lead to social improvements in the ED model. The three central elements of the model: sand dams, terraces and trees, work synergistically to improve the local environment, increasing its capacity to sustainably support the people that live there (see Figure 2). A further feature of ED's approach is the insistence that all projects will be initiated and led by the community, in order to create empowerment and enhance project sustainability.

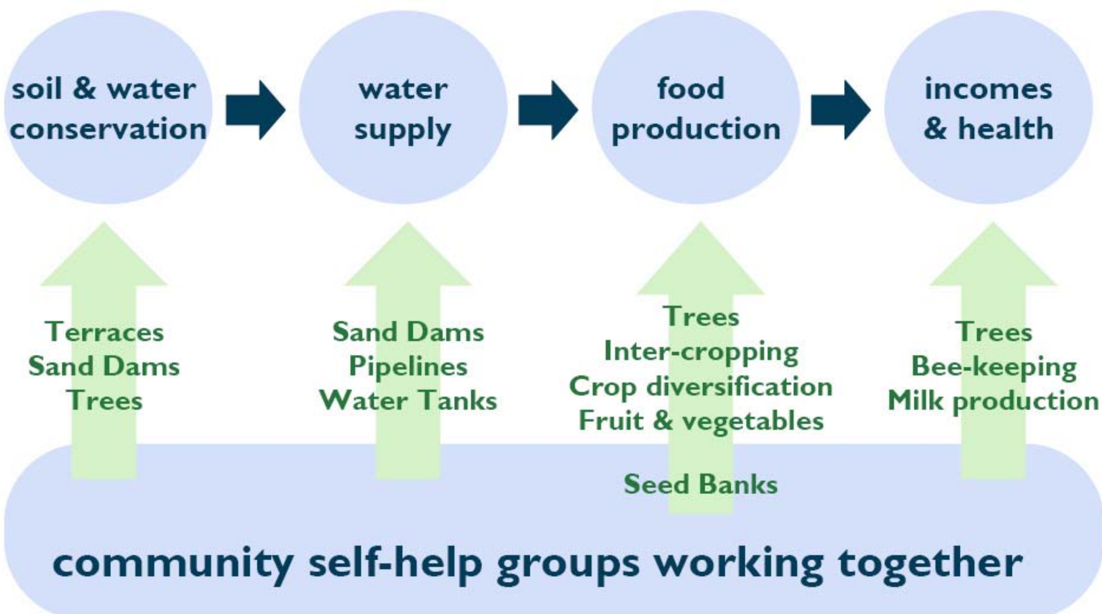

Figure 1: Excellent Development's model of self-help community development, improving water supply, food production, health and incomes through soil and water conservation.

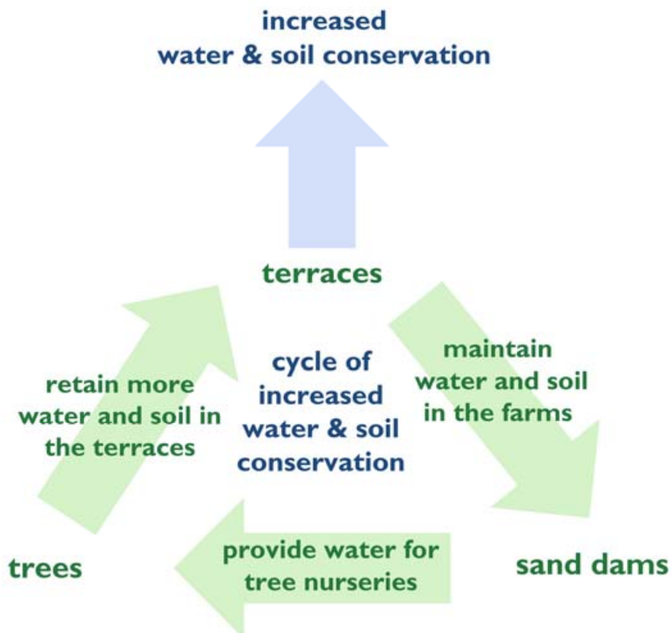

Figure 2: Synergistic interactions of terraces, trees and sand dams

In semi-arid climates water is a key limiting factor on development, a situation which is predicted to worsen in the future due to changes in climate. By improving year-round water supply, enabling trees to be successfully grown, sand dams can reduce the risks associated with climate change, and increase the ecosystem's capacity to absorb carbon dioxide.

Enabling a community to collect water from a sand dam close to their home rather than from a site much further away both frees up the necessary labour time to grow crops and makes it feasible to grow these, with greatly reduced risk of crop failure, due to the proximity and volume of water available. Hence in areas where water availability is both a socially and environmentally limiting factor, sand dam technology can make a significant contribution to livelihood improvement, while simultaneously enhancing a community's capacity to adapt to future changes in climate by providing a low-cost solution to water provision.

After looking at the importance of soil and water conservation in semi-arid Africa, we will look at how sand dams fit into the Excellent Development model, and their relevance as a climate change adaptation strategy. By learning from field experience and disseminating best practice, this technology could potentially be successfully implemented more widely in semi-arid regions.

1. The Challenge of a Semi-Arid Climate

Excellent Development works with community groups in Machakos, Makueni and Kibwezi districts, Kenya, lying between latitude 37°47'E to 37°52'E and longitude

1°19'S to 1°22'S. The vegetation is predominantly dry woodland and bush, with medium to low potential for plant growth (Kigomo, 2003). The region is characterized by low, unreliable and erratic rainfall; when rain does fall, it mostly falls as intensive storms (Rockström, 2000). There are two rainy seasons, between March and May (with mean rainfall 200-300 mm) and October to December (mean rainfall 250-460 mm). (Kigomo, 2003). However, it has been estimated that as much as 50% of rainfall may be lost through soil evaporation alone (Cooper et al, 1987; Wallace, 1991; Allen, 1990), and water shortages are a constant risk.

In semi-arid regions, severe crop reductions caused by a dry spell occur on average 1-2 out of 5 years, and total crop failure caused by drought occurs once every 10 years. (Rockström, 2000). Poor soil fertility is also a key limiting factor, illustrated by the highly negative soil nutrient balances in Kenya (Stoorvogel and Smaling, 1990).

Conservation of water and soil to improve productivity are therefore key agricultural priorities, along with finding ways to maximise productivity from the resources that are available (Rockström, 2000). However, environmental problems in the region have been exacerbated by an expanding population, and the best predictions indicate that the situation will be further worsened by imminent changes in climate.

The Intergovernmental Panel on Climate Change (IPCC) predict that in Africa by 2020, between 75 million and 250 million people will be exposed to increased water stress due to climate change. Agricultural production in many regions of Africa is also projected to be severely compromised by climate variability and change. The length of growing seasons and yield levels are expected to decrease, particularly along the margins of semi-arid and arid areas. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020 (IPCC, 2007, p.13). It has been estimated that 46% of Africa's land area is vulnerable to desertification (Granich, 2006), making efforts to combat soil erosion and water shortages essential in order to sustainably manage ecosystems in the changing climate.

The importance of soil and water conservation as an adaptive measure to climate change has been noted elsewhere (NEF, 2006; IPCC, 2007). As Yamin et al. (2005) note, where communities live with various risks, coupling risk reduction and development activities can provide additional adaptation benefits. Solutions that enable a community to adapt while also enhancing their capacity to adapt to or cope with future changes are therefore of particular interest and such strategies should be given particular consideration when evaluating policy options. The approach used by Excellent Development to support community livelihoods in semi-arid areas can provide just such an opportunity.

2. A Solution, using Sand Dams

Sand dams are a deceptively simple technology that provide an appropriate solution to the problems of a semi-arid climate. One of ED's objectives is to promote the benefits of sand dams and to disseminate best practice derived from its 25 years experience of building them. Here we review the available information on sand dams, and their links to trees and terracing in the ED model.

Various types of groundwater dams have been built at least since Roman times (Nilsson, 1988) but they have not attracted systematic study until very recently. Their interactions with the environment are only now being investigated, so we can only rely on non-scientific observations of their impact. They appear to have very positive effects in this sphere, improving water conservation and enhancing biodiversity. The photographs in Figure 3 illustrate one of ED's project sites before and after a sand dam had been built.

Figure 3: Manzaa valley in 1984 (left) and 2002 (right)

Rockström (2000) notes that although sub-surface and surface dams such as sand dams can make the highest contribution to drought risk reduction of a range of water harvesting techniques, their adoption remains low due to the need for a relatively high level of investment and high level of know-how. However, when compared to a full range of water harvesting techniques (Mati, 2005), sand dams are the second cheapest, providing water at US$0.8/$m^3$, compared to around ten times that for an above-ground water tank (the cheapest was the subsurface dam at US$0.7/$m^3$). Strategies to increase the successful implementation of sand dams could therefore be of great value in addressing water supply problems in vulnerable areas.

A sand dam is a reinforced concrete wall built across a seasonal river bed - 2 to 4 metres high and up to 90 metres across. A pipe can optionally be built into the dam, going up to 20 metres upstream. Over one to three rainy seasons, water floods the valley and flows over the dam; as it does so sand particles settle in the reservoir, while the lighter silt is washed downstream. Eventually the reservoir is full of saturated sand, with around 40% by volume being water. A sand dam of this scale will hold 2 to 10 million litres of water. Storing water below the surface greatly reduces evaporation losses as well as contamination risks as parasites are unable to breed in groundwater (Hut et al, 2007).

Water is collected either from the pipe on the lower side of the dam, or by digging scoop holes in the sand behind the dam to access it.

Sand dams have a wide topological application, they are usually used on gradients of between 0.2% and 4%, but have been seen on slopes of 10 to 16% (Nilsson, 1988) ED experience agrees with Hut et al. that ideally, a point where base rock is near the surface must be found to reduce building costs as well as reduce seepage downstream. The precise dimensions of the dam of course depend on the site, and one of ED's current projects is the identification and specification of the design parameters to enable successful dam building by other interested parties.

Rockström (2000) raises the importance of considering both physical and social applicability when selecting a water harvesting solution, emphasising that bottom up approaches help ensure ownership and sustainability. The practical experiences of Excellent Development's field work concurs that the successful building of sand dams depends not only on correct design, but also on community ownership of the project. Without community ownership the relatively small amount of work required to ensure correct functioning of the sand dam may not be carried out. For example, if terraces around the sand dam are not maintained, soil may wash into the dam, lowering its effectiveness.

It is an essential part of Excellent Development's strategy that the charity only funds the building of dams where communities want them, as demonstrated by their willingness to collect all the water, sand and stones required for construction and to contribute their labour to build the dam. Effective community engagement creates ownership of the structure and gives the community group a vested interest in maintaining it, as well as an understanding of why and how it should be maintained.

Up to 35% of water from saturated sand can be extracted, that is, up to 350 litres of water can be extracted from every cubic metre of sand (Nissen-Petersen, 1997). Assuming that mechanical abstraction for irrigation is low or absent (which is the case in ED project areas), each sand dam will provide a year-round clean water supply for up to 1,200 people, their animals and nurseries for trees and vegetables. Furthermore, the effect of permanently improving water availability in a 20km radius means that a sand dam may indirectly benefit up to 100,000 people, as this is the maximum distance travelled to get water during times of drought.

Hut et al. note that local residents testify that after dam construction there is more water both upstream and downstream, however data on groundwater flow over a sufficient time period to verify this experimentally are not yet available. Furthermore, little is known about the relationship between groundwater and climate (IPCC, 2007, p.437) Nevertheless, improvements in water conservation and groundwater recharge mechanisms will no doubt help to lessen the impacts of climate change in semi-arid areas.

Terraces have been shown to have a very significant effect on reducing soil erosion in semi-arid areas. (Thomas, 1997). ED advocates the use of terracing around a sand dam to improve its effectiveness, and encourage communities to terrace on individual farmers' land.

Forestry has a recognized role in enhancing conservation and mitigating desertification in the Eastern and Southern African region, with the main constraint in dryland areas being the lack of sufficient water to ensure establishment of seedlings (Kigomo, 2003). Establishing tree nurseries close to sand dams allows this constraint to be effectively removed. When planted out, the raising of the water table by a sand dam enables trees and vegetation to grow. Tree planting can also improve the micro-climate so it is more favourable to agriculture. (Reij, 2006). The presence of trees and vegetation on terraces helps maintain the integrity of the terraces, and also results in a net increase in moisture in the soil due to their lowering the soil temperature and breaking up the soil structure.

Individually, terracing, sand dams and trees can make significant contributions to the problems of soil and water conservation, however together they work synergistically, increasing the success rate and sustainability of the solution.

3. Sand dams' Contribution to 'climate proofed' Development

Semi-arid areas currently face significant risks of adverse changes in climate. The IPCC report emphasises that poor communities in high-risk areas will be particularly vulnerable to climate change due to their limited adaptive capacities and greater degree of dependence on climate-sensitive natural resources (IPCC, 2007, p.12).

It is clear that climate change endangers the chances of meeting the Millennium Development Goals (MDGs). Hence calls from many development organisations for 'climate-proofed' development (Biemans et al., 2006). In the area of water supply this can be achieved by increasing water storage capacity, enabling economic growth to become increasingly delinked from rainfall.

Enhancing adaptive capacity and adaptation per se are complementary but not always identical strategies for dealing with the impacts of climate change. In many cases development priorities and climate imperatives can pull in opposite directions, and systematic cost-benefit analysis to identify the optimal course of action is hindered by a lack of firm predictions and sound cost estimates, which can paralyse decision making.

Looking for synergies between the two or between adaptation and mitigation can indicate a preferable development path. For example building a sand dam addresses the short-term development problem of water supply and long-term climate change risk reduction. The Excellent Development model can be considered to enhance the capacity of the socio-ecosystem to adapt to climate change by developing, adapting and mitigating simultaneously.

There is also evidence to indicate that elements of social capital (such as associations, networks and levels of trust) are important determinants of social resilience and responses to climate change, although mechanisms are complex and undefined (IPCC, 2007, p. 456). Membership of a community self help group could be considered in this category. Furthermore it is noted that the enhancement of indigenous capacity is a key to effective participation in the development process (Leautier, 2004; IPCC, 2007, p. 456).

At present, few plans for promoting sustainability have explicitly included either adapting to climate change impacts, or promoting adaptive capacity (IPCC, 2007, p. 20). This will have to change fast if development projects are to be successful. Much has been made of the conflict between development and conservation, however in semi-arid Africa at least, we argue that conservation is in fact a route to development, and the two can work together to create sustainable and increasingly successful livelihoods.

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