Smart 3R Solutions

NETHERLANDS
WATER PARTNERSHIP

Contents

Acknowledgement

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Foreword by International Fund for Agricultural Development

'...With an increasing number of people facing severe water shortages, efficient use of water for agricultural purposes in order to reduce poverty and hunger is a significant issue. Water is the key to food security. We will not be successful in achieving global food security without working on water security first. One of the answers to combat severe water shortages is to capture and store water during the wet periods, so that enough water is available during the dry seasons. As a part of the solution, storing water and using it as a buffer, is particularly relevant given the increasing climate variability, especially as extreme events like storms and droughts occur more frequently.

This publication on Smart 3R Solutions (Recharge, Retention and Reuse) focuses on the functions of land and water buffers as part of integrated basin management and climate change adaptation. Water buffer management can provide scaled locally adjusted solutions that improve the resilience of people and their environments to food insecurity and climatic variability, both on local as well as basin-wide levels. It, therefore, adheres to the principles of Integrated Water Resources Management (IWRM) through the responsible management of both water and land resources.

3R can be applied all over the world as good water management is needed everywhere. The management of a large watershed is often a big challenge. 3R provides tools to unpack these challenges and, on a local scale, simplify these interventions to be implemented with the participation of the local population. 3R solutions give people the means and the confidence to protect their livelihoods and increase their food security by improving local water management practices for multiple use services. This publication gives an introduction to 3R solutions and presents cases of implemented 3R experiences across the world.

The International Fund for Agricultural Development (IFAD), one of the founding partners of the Rainwater for Food Security programme, invests in rural people. It focuses on sustainability and resilience building where investments in environmental policy setting and harmonization, hand in hand with strengthening service capacities, represent a future growth area. IFAD, as many IFIs and development partners, embraces the sharing of knowledge and fosters innovations. 3R solutions give societies at large and local communities the opportunity to achieve this, be it by combining local and external

technologies, be it by strengthening local and higher-level institutions.
This smart 3R solutions booklet published by the Netherlands Water Partnership (NWP) and Netherlands Enterprise Agency (RVO) in the context of the Partners for Water Programme[1], enables us to learn more on 3R solutions and experiences so that we can achieve more in solving global water related challenges.
I wholeheartedly recommend you consider this booklet as an effort to change your and fellow development actors' attitudes and behavior towards embracing unconventional approaches to 3R solutions which often straddle the 'neglected' with the 'obvious'.

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1 *Together with ICCO the funder of the publication of this Smart Solution Series edition.*

1. Introduction

1.1 Smart solution series

'The Smart Solutions Series' publications by collaborating Dutch water development organisations[2] have become something of a tradition. Six editions have been published since the series' inception in 2007. Today we are proud to present you with this 7th, 2014 edition. The '3R Smart Solutions edition' follows on from the 'Smart Water Harvesting solutions edition'. However, as opposed to the previous edition this edition focuses not only on water harvesting but seeks to offer a wider scope by equally looking at local water management. The case studies result from publications of the 3R consortium (Acacia Water, Aqua for all, MetaMeta and RAIN) and IRC, and can be found on www.bebuffered.com. These case studies take into consideration 3R (Recharge, Retention and Re-use), MUS (Multiple Use Services) and food security.

1.2 The need for SMART 3R solutions

Across the globe people lack access to sufficient sources of water necessary to support their basic living requirements and the production of food. The 3R approach has the ability to make a difference here by making optimal use of the ground- and rainwater available in these areas. By improving local water management practices for multiple purposes, people are given the means and confidence to increase their food security and improve their livelihoods. 3R stands for recharge, retention and reuse. 3R aims to ensure reliable access to water and allow for economic development whilst maintaining a socially and economically respectful relationship with the environment.

The buffer function, or in other words the capacity in which an area or terrain has the ability to hold water, serves as our point of departure. This buffer function allows for the efficient handling of surplus or shortages in water, or other shifts in demand as a result of climate change or population growth. An important water buffer is to be found in the upper layers of soil and shallow groundwater. Storing water in this groundwater buffer makes it available

2 *Rijksdienst voor Ondernemend Nederland and Netherlands Water Partnership jointly implement the Partners voor Water Programme, which includes the facilitation of a platform consisting of Dutch water NGO's: http://www.nwp.nl/activiteiten/activiteiten-in-nederland/ngo-platform.php. This platform has been the driving force behind the publication of the Smart Solutions Series.*

for reuse. In addition to groundwater, local surface water storage adds to the water buffer in a region, for example, the collecting and storing of rainwater and surface runoff in tanks and local reservoirs. Managing each of these water buffers in an area or terrain is of vital importance as they offer a solution for water shortages and can provide water drinking water or water for domestic and productive uses. Storing water makes it available for direct or later use. Buffers also make water management more environmentally sustainable. The use of water buffers affects the livelihoods of people, aid their development and provide food security on a local level.

The basic idea behind this strategy is that tackling a local water crisis has not so much to do with allocating scarce water but that it is vital to collect water, extending the chain of water use and reusing the water as much as possible within a basin. It is important in this process to take account all inhabitants and their environment across these basins.

What is the biggest difference with Integrated Water Resource Management? The management of a water basin is challenging. 3R provides the tools for interventions that are easily implemented with local population participation. The water management of a whole basin can be improved upon by intelligently joining smaller elements together. Intelligent here means implementing 3R by adopting an integrated approach. 3R fits very well within the concept of integrated Water Resource Management - 3R is all about putting IWRM into practice.

1.3 What makes 3R solutions SMART?

3R seeks to design and integrate different combinations of water buffering techniques for an entire basin or sub-basin based on the requirements of the population of an area. These requirements take into account multiple uses of water, existing local infrastructure, the way the land is used and the natural environment. 3R seeks to take the local situation into account without getting entrenched in isolated interventions. It is therefore essential to generate an understanding of the buffer function characteristics of an area. There is no standard approach in determining the correct buffer strategy with different socio-economical and environmental circumstances each calling for their own unique approach. 3R integrates management and planning of Integrated Water Resource Management techniques with water -and soil conservation techniques. Accomplishing this on a local level is what makes 3R smart. The combination of Recharge, Retention and Reuse makes up the core of 3R.

Recharge

Recharge may derive from a number of sources, for example, the interception of rain and run-off water (natural recharge), from the increased infiltration of natural processes by manmade interventions (managed aquifer recharge-MAR) or it can be a by-product from an alternative source (for example inefficient irrigation or leaking pipes in water supply systems). Recharge requires the management of natural recharge, the application of artificial recharge and the controlling of incidental recharge. Both ancient and highly innovative managed aquifer recharge techniques exist. An example is, the recharging of wells so that they directly infiltrate at field level, like is the case in spate irrigation. Natural recharge management is equally important. Natural recharge may be derived from elements in the landscape that slow down or retain surface run-off, like terraces, low bunds, depressions or intelligently designed roads. Natural recharge can also be derived from direct infiltration through better tillage techniques and mulching. Recharge is essentially the charging and recharging of the water capacity of an area.

Retention

Retention is the storage of recharged groundwater, surface water or rainwater in one place. The slowing down of the lateral flow of ground water and the creation of a buffer in the shallow groundwater can result in groundwater retention. Surface water retention means that water is held where it flows to, for example, in ponds or depressions. Retention can also be achieved through manmade systems like below surface tanks or rainwater jars. Retaining water allows for the extension of the chain of water use.

Reuse

Reuse is the third factor in buffer management. 3R's biggest challenge is to allow water to circulate as often as possible. Scarcity is not resolved simply by managing demand by reducing usage, or the promoting more efficient use, it also requires actions to keep water in active circulation. Three processes are important in managing reuse: controlled (non-beneficial) evaporation, management of water quality and the ensuring of availability and accessibility over time. Controlled evaporation may be achieved by efficient irrigation. This type of irrigation reduces the evaporation loss in the irrigation process and makes sure that the majority of the water used directly benefits the crops. It is important to strike a fine balance between keeping good soil moisture and avoiding loss of water through evaporation. The second process of managing the water quality is largely dependent on the required quality for the intended purpose, as different purposes demand different qualities. It is important therefore that high-quality water is not mixed with a lower quality grade of water. Special emphasis and effort must therefore be placed on keeping the water quality within safety thresholds when reusing water, or in the circulation of water. To thoroughly ensure water availability and accessibility requires water not be allowed to migrate to an area from which it is hard to retrieve or reuse. Recharged water in a dry unsaturated buffer, although not lost, is hard to retrieve and difficult to bring back into circulation. Saturated buffers on the other hand allow for easy retrieval, therefore increasing 'wet water buffers' is an important challenge for 3R.

MUS (Multiple Use Water Services www.musgroup.net)

Multiple-use water services (MUS) starts by looking at people's water requirements. When one takes a more holistic approach to available water resources and water requirements, it becomes possible to make more cost-effective and sustainable investments. Such an approach allows for a broader range of health and livelihood benefits compared to the adoption of single use systems.

Multiple-use water services meet people's domestic and productive requirements through the efficient utilization of water resources. A MUS approach takes into account different water resources, the quality requirements, the necessary quantity, the requested reliability and the distance to the point of use. A MUS approach can be adopted to plan new water services or to upgrade existing domestic systems or irrigation services.
MUS can be seen as an innovative approach that takes people's multi-usage water requirements, local opportunities and potential constraints into consideration.
Securing the availability of water by improved buffer management has a range of positive effects on the local population. It is important to fully understand these effects. Buffer management is based on a fundamental understanding of the way it touches on the priorities and potential of the people living in the area itself (from access to drinking water to the potential for economic development). This notion should be the starting point for the planning and design of the 3R solutions. Increasing water availability lies at the heart of local development and offers people the opportunity to build upon their current basic activities and increases their food security.

There are three important arguments in support of 3R:

1. **Climate change adaptation**

   Changes in rainfall may influence the livelihood of people and their economy. Water storage plays a deciding factor in the ability to adapt to climate change. Water storage is a key component in bridging momentary gaps between demand and availability of water. Many advantages are to be found in making use of the buffer function of groundwater, surface water and storage systems. These systems have the ability to offer people sufficient access to drinking water and provide water for cattle, agricultural purposes and other productive purposes. Access to water also benefits the environment and the wider ecosystem. Storage of water allows for secure levels of reserves that can be used in times of need.

2 Recirculation in the water chain

Water management is often limited to the paradigm of water resource allocation, availability and efficiency. It often fails to take into consideration the buffer capacity, water circulation or the re-use of buffered water. 3R can substantially contribute to increasing the quantity and quality of water resources. The use and reuse of buffered water allows for the increased availability of water, as it circumvents water allocation conflicts through simply using and re-circulating the water.

3 Green water management

Buffering water in groundwater results in improved soil moisture and increases the availability of shallow groundwater. This way of buffering makes an important contribution to 'green water management'. Green water management is the management of soil moisture based on improved tillage, mulching, physio-chemical and biological processes. By infiltrating water into the soil, 3R contributes to green water management in a way that leaves a positive footprint on both ecosystems and agricultural production.

The following case studies are replicated (with small edits) from the following publications:

From the full 3R books which can be found on www.bebuffered.com.

- Steenbergen, F. van, Tuinhof A., and L. Knoop. 2011. Transforming Lives Transforming Landscapes. The Business of Sustainable Water Buffer Management. Wageningen, The Netherlands: 3R Water Secretariat.
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And

- Acacia Water, IRC and Aqua for All. (2014). Integrating water resources and water demand to improve drought resilience and build water strategies.

2. Case studies

2.1 Re-greening – improved indigenous soil and moisture conservation, Burkina Faso and Niger

Introduction

For many years the Sahel has remained a by-word for resource degradation and destitution. In the devastating drought of 1969-1973 many lives were lost and livelihoods of many were destroyed: trees and livestock died, water levels dropped, yields for staple crops such as sorghum and millet declined and sand dunes expanded at the deserts fringes. Areas with high population pressure – such as Niger and Burkina Faso – were particularly hard-hit.

From the 1980's onwards however the Sahel has also been the scene of a transformation. Sahelian farmers themselves have steadily turned some of the world's most arid lands into productive farmland – helped by a period of reasonable rainfall. In Burkina Faso and Niger farmers applied traditional systems of agro-forestry, water harvesting and soil management, which were modified to suit the changing circumstances implemented to scale; contributing to food security. In Burkina Faso an estimated 200,000 to 300,000 hectares were re-invigorated by farmers developing zaï planting pits and stone bunds – yielding an extra 80,000 tons of food annually – enough to feed 500,000 people. In Niger, 5 million ha were rehabilitated with improved agro-forestry systems – making use of the dormant root systems. This has added an estimated 20% to the income of 4 million people.

The scale at which these changes emerged and the process of innovation and adaptation dispels the notion that prospects for arid, land-locked areas are small, and that investing in them is not rewarding. In this regard, the experiences in Niger and Burkina Faso have been the basis for African Regreening Initiatives elsewhere on the continent. Building on this farmer-led transformation, the idea of a 'Green Wall for the Sahara' was proposed by former Nigerian President Olusegun Obasanjo and presented to the Community of Sahel-Saharan States and the African Union. The Action Plan adopted by the African Union –and European Union includes cooperation as a priority, to 'address land degradation and increasing aridity, including the "Green Wall for the Sahara Initiative"' as part of regreening the Sahel.

Techniques

The techniques used in the regreening of the Sahel were not new – but they were improved upon and modified to suit current challenges and contribute to food security. Most of the experimentation and dissemination was farmer-led. An icon personality for instance is a Burkinabe farmer called Yacouba Sawadogo who began organising farm visits and semi-annual market days to promote planting pits. Yacouba also operates a seed exchange. Farmers brought samples of the crop varieties they cultivated in their zaï, deposited the seeds with Yacouba and then, following his advice, selected the seeds they wanted to plant that season. In the words of a leading soil scientist: 'Yacouba had more impact than all soil and water researchers combined'. Another example is the farmer starting a zaï school – training fellow farmers in the zaï technique on a gravelly area next to the road.

Zaï pits, Burkina Faso

This grew to a network of 20 schools with some 1000 memrs – each group was charged with improving its own piece of degraded land. Both governments and NGOs supported the process. For the development of specific compost, pit-training sites were established that included, for instance, a hectare of cultivated land as an example to encourage trainees. Depending on the extent of the support programme, the trainees would then be able to take home compost and build, applying it to their own pilot plots. Particularly in Burkina Faso, women's groups became an exceptional feature of the widely accepted development of zaï compost farming.

Set up shortly after the drought emergencies, earlier large-scale projects had misfired – as they failed to engage the land users.

Zaï

Zaï planting pits consist of 'mini-basins' that store rainwater for plant growth and concentrate crop nutrients. Planting pits are excavated in grids. Planting pits of around 20 cm in diameter and 10-15 cm in depth may amount to 10,000-15,000 pits per hectare. Their dimension and density vary from area to area – depending on the crop grown, the soil conditions (they do not do well on hydroscopic soils for instance) and the need to harvest water. Larger pits and more spacing between them allow more water to be harvested. The innovation, which was developed through farmer's experiments in Burkina Faso, was to increase the depth and diameter of the pits and to add manure to them. Once excavated, the pits capture other materials – for instance wind-blown soil and leaves. Termites are also attracted to the organic material in the pits. They form an army of 'soil engineers'; digging small tunnels that improve the soil structure and cause water infiltration to double, convert organic material and make nutrients available to the plant roots. The pits with the organic material will retain water in dry spells, allowing crops to survive. Sorghum is the preferred crop because of its adaptability to temporary inundation that may occur in the planting pit. Zaï combine well with stone contour bunds, these reduce the speed of runoff and allow even more water and soil retention.

Stone contour bunds

Traditionally, stone contour bunds were also been used in Burkina Faso, but the challenge was always to follow the contour lines, especially where the landscape is flat. Following the introduction of a low-cost water spirit for measuring land levels it became much easier to determine the correct alignment of stone bunds. Mastering the skill of using the level took no more than two days. The more effectively aligned stone bunds allowed runoff to spread effectively and evenly through the field and trickle through the small opening between the stones. The practice improved soil condition by trapping sediments and organic matter within the plots thus preventing it from washing away with the rain.

Modified traditional agroforestry

At the same time in Niger farmers developed innovative ways of regenerating and multiplying valuable trees whose roots have been lying dormant underneath their land. Based on their experience in managing local woodlands, farmers starting experimenting with a process that became known as Farmer Managed Natural Regeneration (FMNR). Among the mature root systems in the field, farmers would choose tree stumps based on the usefulness of the species. The tallest and straightest stems would then be selected, nurtured and protected. At the same time other stems would be removed.

Stone bunds with Sorghum, Burkina Faso

The selected stems would be pruned whilst other stems would be continuously removed to further promote their growth and production. The removal of stems enabled the growth of other crops between and around the trees, creating an ingeniously modified agro-forestry system. The trees generated a number of important benefits: (a) they improved the local micro-climate by reducing wind speeds and evaporation – thus reducing the impact of drought and heat; (b) they provided fodder for livestock (enough for half of the year); and (c) they provided fruits, firewood and medicinal products. Some species also added nitrogen to the soil.

Costs and benefits

The benefits in terms of food security and farm productivity have been substantial, explaining the speed with which innovations have spread from farmer to farmer. Most of the improvements are done by farm labour in the off-season. Though these labour inputs are substantial, there is no opportunity cost for them. This was in itself an innovation – as traditionally work on Zaï's was unheard off in the dry season.

Zaï and contour bunds

Establishing zaï structures at the beginning of the dry season consists of two main activities, namely digging the pits and covering the bottom of each pit with a 3 cm clay layer. Zaï pits or (planting pits1) come in different sizes and densities (pits / ha), and therefore the amount of labour and costs also vary. Where zaï is combined with stone contour bunds, the bunds also need to be constructed. Below are a typical ranges of costs for the establishment and maintenance – including the replenishment of manure – of the pits and bunds.

Without these measures, productivity is extremely low: 80 kg of sorghum/ha. Zaï and stone bunds can raise yields to 300 to 400 kg/ha in a year of low rainfall to up to 1500 kg/ha in a good year. Experiments show that in particular it is the concentration of nutrients that makes the difference. Further spin-offs of the new Zaï systems include the development of a market for manure. Herders have started to systematically collect the manure after harvesting for sale since an increase in demand has led to a doubling of the price.

Establishment costs and recurrent inputs for Zaï and contour bunds

Zaï and contour bunds: establishment input and costs per ha	
Input	Cost (USD)
Labour	27-175
• 2-150 person days for pits	
• 25 person days for stone bunds	
Equipment and tools	50
• hoe, knife, digging sticks bucket, lorry	0
Matrerials	
• clay (0,5m3)	
Total	77-175

Recurrent inputs for Zaï and contour bunds

Zaï and contour bunds: recurrent inputs and costs per ha per year	
Input	Cost (USD)
Labour	21
• 20 person days for the manure	
• 1 person day for the stone bunds	
Equipment and tools	6
• Wheel barrow rental	
Materials	0
• ash and wet straw	
Agriculture	2
• manure(100kg)	
Compost tansportation	2
Total	30

Agroforesty

The costs of implementing the innovative agroforestry system are associated with individual labour and relates to the time spent on stemming, pruning and cutting the trees. The benefits are considerable, in Niger in the past 20 years over 250,000 ha/year have been replanted, adding up to 5 million ha. At an average of 40 trees/ha this adds up to a total of 200 million new trees. These trees allow for a range of benefits, which include reducing wind speed and evaporation, and producing at least a six-month supply of fodder for livestock, firewood, fruit, and medicinal products that farm households can consume or sell. Certain tree species (Faidherbia Albida for instance) also enhances the soils fertility by adding nitrogen to the soil. If each tree produces an average annual value of USD 1.2 (firewood, fodder, fruits, medicinal products, improved soil fertility, increased crop yields, etc.) this sums up to an annual combined production value of some USD 240 million. This figure does not yet include the value of the timber or the carbon sequestered by the standing tree stock. With 4 million individuals are involved in the regreening process, an increase of USD 60 to the average annual income per capita is realised, whereas the average annual income per capita income in Niger is currently in the region of USD 280.

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2.2 Using natural landscapes, Turkmenistan

Introduction

Natural surfaces – called takyrs – are used to harvest water in the extremely dry Turkmenistan Karakum Desert. People are to benefit from takyrs for their consumption, food security and economic purposes. Takyrs are large stretches of desert landscape characterized by a flat or gently sloping topography. Deposits of clay material aggregated in local drainage zones make up these Takyrs. In Turkmenistan these areas cover a surface totalling some 19,000 km2. Of this 11,300 km2 is occupied by takyrs that are larger than 1 km2. Impermeable by nature, they have a low infiltration rate and, because of their sheer size, deliver substantial volumes of runoff even from the scarce amounts of rainfall they receive. In situations where the use of surface streams and aquifers is not an option, takyrs are effective in harvesting water. It is thought that takyrs in Turkmenistan can produce 350-450 Mm3 of water per year. Of which only a small part is currently being utilised for productive purposes.

Buffer systems

The Karakum Desert covers most of Turkmenistan. It is characterized by a warm dry summer followed by a short winter. Rainfall is usually 110-200 mm per annum and is concentrated in the cooler winter months. The desert population has developed different buffer systems to save runoff during the humid periods to allow them to survive the long dry parts of the season. Whilst the main economic activity is cattle herding, households also engage in small-scale farming for home consumption and supplementary food purposes.

The qualities of takyrs make them a perfect surface to produce excess water. Different techniques are used to store the run-off for later productive use: soils, shallow aquifers, closed reservoirs and open ponds. All the techniques make use of the low permeability of the natural landscape for the rainwater to be concentrated. Often two or more methods are used and conjunctively operated to gain the most out of the small amount of rain available. The main storage techniques are:

- ***Khaks:*** These artificially made depressions collect water from takyrs during the rainy spells and store the water in open-air reservoirs. They are predominantly used to provide water for the livestock for 2-4 months into the spring. Due to the high evaporation rate of this environment these ponds can only be used productively in the first part of the dry season. They are not suitable to provide water for human consumption as water held in open storage facilities is easily contaminated. The investment necessary to construct a small khak is around USD 350; a large system may cost up to USD 960.

- ***Sardobs:*** Water can be alternatively stored in closed cisterns. These sardobs used to be constructed out of lime mortar and bricks with a covering dome. Modern versions make use of concrete. Sardobs collect surface run-off water; a typical cistern has the capacity to hold up to 500 m3 of water. Two or more structures are built in the same location where additional storage is required. These constructions yield clean water, suitable for domestic use and for livestock's watering in the drier months of the year. The freshwater obtained can be mixed with brackish aquifer water to water livestock for an extended period of time. The construction of a single unit can cost up to USD 8750.
- ***Chirle:*** An alternative is to store excess water in the sandy soil shallow aquifer underneath the takyr and to withdraw the amount needed by using one or more wells. The run-off water is collected in a excavated depression at 2-12 m in diameter from where it regenerates the permeable sandy layers underneath the impermeable takyr. The concentrated water is preserved in a freshwater a lens above the saline aquifer and it stays separated from the salty water due to its lower density. One or more wells can be dug in and around the depression. Contrary to the other technologies used in the Karakum Desert, the storage capacity of these so-called chirles is flexible. Constructing such a structure cost USD 2500 when only a single well for human consumption is in use. The cost increases to USD 21,000 when 10 wells are dug. In the case where the wells are also utilised for livestock water or to improve the rangeland, the cost rises to USD 36,500. Despite the hefty initial investment, maintenance costs are relatively low, at USD 115-192 per year. Multiple households commonly share these associated costs with the entire community maintaining the chirles in use.
- ***Oytak farming:*** Oytaks are natural takyr depressions covered with a layer of sandy soil that, during the rainfall, becomes moist and can be used for farming. Oytaks are traditionally used to produce fodder, but alternatively they can also be used for crop and tree cultivation. Oytaks often gain water from the natural sloping surface of takyrs, but in certain cases run-off water can be conveyed through furrows. When plants are growing, oytaks tend to act as both a sand trap and to decrease the surface area of the takyr. The construction of one furrow unit requires minimal structural work and has a cost of USD 24.
- ***Modern takyr cultivation:*** Mechanised farming has potential in these harsh environments. A system of parallel furrows can be excavated perpendicular to the takyr slope to form a series of smaller consecutive catchments. Each catchment is confined in the lower side of this modern takyr by a furrow in which the plants are grown. This system

Chirle well in Madau, western Turkmenistan (Photo credit: Luuk Fleskens)

Oytak after runoff event (Photo credit: Luuk Fleskens)

Oytak in Central Karakum (Photo credit: Luuk Fleskens) relies on that by reducing the catchment area, a better runoff coefficient is obtained and the water is therefore used more efficiently. In other arid regions similar farming practices are used to improve rangeland productivity. In normal cases an inter-furrow distance of 7-12 m is used depending on the climatic characteristics. In milder climates even fruit trees and melons can be cultivated using an inter- space of 20-25 m. These modern systems require a substantially higher investment and technological input than the traditional techniques, but they are also more profitable in their potential.

Benefits

These different water buffer systems cater for multiple use services, for example, providing freshwater for human consumption as well as on the other hand serving economic activities in the difficult desert conditions. Furthermore, there is potential for larger-scale desert farming through the use of modern takyr cultivation taking into consideration that a substantially higher investment is required. A household that has a directly available source of freshwater from one of the water harvesting techniques will save money that would otherwise have to be used for trucking water, or for pumping deep brackish water. In addition to the before mentioned benefits farmers will benefit from increased yields, healthier herds and lower dependency on piped water.

Water brings potential for better conservation of natural resources in an environment where herding is the main source of income but also comes with some concerns. When water is concentrated the animals tend to be concentrated in the areas immediately surrounding these spots of available water. In these scenarios the risk of overgrazing and soil degradation becomes magnified. On top of that without animal trampling around and breaking the surface crust the soil tends to create a biogenic crust that can favour desertification processes. Nevertheless, pressure on natural resources caused by overgrazing can be decreased by augmenting the available sources of water and by spreading the herd over a larger area.

Modern takyr cultivation seems to be a profitable route to take for agricultural production. High Internal Rate of Returns (IRR) have been estimated: 130 for melon production, 38 for quince, 41 for grapes and 30 for pomegranates[3] . When cultivating melons using oytaks the IRR is 99, based on average yearly conditions, assuming no external labour is hired in and the average production of melons is 1200 kg.

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3 *Fleskens et al., 2007*

Sardobs and chirles can be only be used for human consumption and for enhancing food security. Sardobs showed an IRR of 14. For chirles with a single well the IRR was 6.9 and 8.6 with 10 wells in use. These figures are based on a situation where no external labour is required, with the closest source of freshwater 20 km away.

When the water harvesting techniques are used to create new rangelands in the central part of the Karakum, sardobs showed an IRR of 49, chirles 61 and a small khak 583. These figures are based on a number of assumptions: no external labour sources are brought in and no rangeland degradation take place. The IRR shows positive values that guarantee a positive return in cases where the water is used to create improved rangelands.

Future

Investment in water harvesting from the natural landscape has the potency to be profitable in a number of ways. khaks appear to be the cheapest alternative in terms of cost of water per volume when offset against other alternatives. Nevertheless, khaks do have their restrictions as they can only be used for a number of years and due to their open air nature are unfit for human consumption. Sardobs therefore are the cheapest way to produce safe drinking water. This is particularly true when alternative sources of drinking water are over 10 km away. The water harvesting systems for productive purposes each show very attractive prospects.

Central state investments in desert developments have ended after the break up of the USSR and only a few new structures have been constructed since. There is a great deal of unutilized potential, even in this inhospitable environment, to make more use of the natural harvesting basins. Local farmer associations may play an important role in managing the necessary capital and in creating instruments that favour the construction of water harvesting structures.

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2.3 Plastic mulches, biodegradable alternatives, China and US

Introduction

Plastic mulching has seen a meteoric rise over the last twenty years; especially in China where it is so popular that in some areas entire valleys glimmer from being wrapped in plastic mulch. According to 1999 figures[4], it is estimated some 9.5 million hectares are covered in plastic mulch; these figures are expected to have at least doubled over the last years. The technique has become very common especially in drought prone areas in North West and South West China like Xinjiang and Yunan. The popularity of plastic mulching is partly due to its ability to create a microclimate that allows for better control of water, temperature and the uptake of nutrients. Plastic mulching allows for improved cultivation and requires substantially less weeding. The technique equally ensures that the water is kept within reach of the crop roots and prevents the evapo-transpiration of water. The plastic layer, aside from ensuring effective internal water circulation in the topsoil layer, also allows for an improved uptake of nutrients by preventing nutrient leakage during the occasional rainfall. Furthermore, it allows for the regulation of soil temperature, which benefits the germination process. Plastic mulching can significantly contribute to improved crop growth and has the ability to ensure food security.

Plastic mulch is very popular in China (photo credit: MetaMeta)

4 *According to Brown, 2004*

There are a variety of colours (transparent, white and black) of mulch in use, each with their own specific impact on factors that influence crop growth. Transparent sheets for example are specifically useful in supporting early season crop growth with the clear nature of the sheets allowing for the sunlight to pass through the sheets. Black sheets on the other hand block photosynthesis, which allows them to control weed growth. White, silver or aluminium sheets are used to re-direct sunlight that has passed through the leaf canopy back to the leaves, making for higher yields. White mulching equally reduces the soil temperature thus allowing for crop cultivation, even in high temperatures. Apart from varying in colour, the sheets also vary in thickness and porosity.
These variations in turn have causal effects on water circulation, nutrient uptake and longevity. The plastic sheets are manually or mechanically applied and punctured to allow for the growth of plants.

Both the application and removal of the plastic mulch requires additional labour and expense. The increase in crop production outweighs these extra costs as crop production is increased on average by 50%, but in exceptional cases there have been increases of four to five times the normal production[5]. The costs for procuring the mulch are partly compensated by savings on: labour, energy weed removal costs, fertilisers and irrigation. For example, the drip irrigation system commonly used in combination with plastic mulch, is much more economical in its use of energy and water than systems like furrow irrigation or overhead sprinklers[6].

Using plastic mulch does however pose certain financial and environmental challenges. Plastic mulch is expensive, an approximate sample price being $0,14 per square metre or some $700 per hectare. The cost of removal and disposal of mulch in the United States is estimated to be $250 per hectare[7].
At the same time there are environmental concerns and challenges to be tackled, for example, what to do with the plastic when its use has come to an end (which can range anywhere from one to ten years, depending on the type of plastic and how it is used.)?

Biodegradable alternatives

Both this financial aspect as well as concerns over mulch residue in the soil has resulted in a search for biodegradable alternatives. Biodegradable plastics were first introduced to

5 *Sanders, D.C., 2001; Osiru and Hahn, 1994; Ashrafuzzaman, M. et al. 2011*

6 *Kovach et al. 1999*

7 *Schonbeck, 1995; Olsen and Gounder, 2001*

agriculture in the 1980's, but unfortunately at the time these plastics did not sufficiently degrade[8] and instead fragmented into smaller particles[9]. By the 1990's, inaccurate claims about these products started to create confusion concerning the term 'biodegradable'[10]. Today, some 20 years on, this confusion has not waned but actually laid the groundwork for growing scepticism. On top of that, commercially available biodegradable products are two to three times more expensive than their conventional black mulch counterparts.

The effect that biodegradable mulch has on the soil health and microbial ecology is unknown. Conventional plastics may form micro-plastics, particles smaller than 5mm in diameter, which absorb toxins present in the environment and as a result effectively concentrates them[11]. A primary concern, although unknown, is whether biodegradable mulch equally absorbs and therefore concentrates toxins found in agricultural soils - otherwise known as pesticide residues. Nor is it known what effect this might have on an agro ecosystem.

Black plastic mulch used on a pineapple plantation, Kenya (Photo credit: MetaMeta)

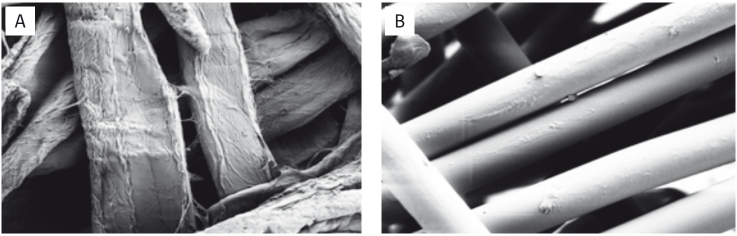
8 *Changing chemical structure to result in a decrease of physical and mechanical properties, [per ASTM D883-11, 2011*

9 *Riggle, 1998*

10 *Yabannavar and Bartha, 1994*

11 *Zarfl and Matthies, 2010; Teuten et al., 2007; Mato et al, 2001*

The possible relationships between climate, soil microbiology, soil biochemical processes and the break down of biodegradable mulch is currently being studied.



SEM photomicrographs of cellulosic (a), SB PLA (b) and MB PLA (c) specimens at 1000X

A key survey into understanding the current level of knowledge about plastic and biodegradable plastics was conducted amongst innovative and leading farmers in Washington, Tennessee and Texas[12] prior to the field study. 75% of those surveyed (n=34) had used plastic mulch and were satisfied with the results, however plastic mulch removal was a cause for concern, especially as recycling facilities were not available in most of the areas. Almost 25% of the farmers indicated that they had used biodegradable mulches. From that number, 28% felt that this type of mulch provided adequate weed control and water/moisture conservation. The unpredictable and incomplete biodegradation process, combined with the cost of removal of un-degraded mulches, led to dissatisfaction by 60% of the users. The results of the survey combined with our field study indicate that today's biodegradable mulches are still not satisfactory. Resistance remains, despite a third of the farmers believing biodegradable mulches are suitable for the crops they grow. The barriers for adopting biodegradable mulches include: (high) costs, lack of availability and a general lack of knowledge about biodegradable mulches. Particularly in relation to efficiency and the impact these mulches have on soil health and quality. Continued research into biodegradable mulches should provide answers to some of these concerns.

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[12] *Miles et al., 2009*

Table 1. Commercially available agricultural mulches labelled as biodegradable

Mulch Product Name	Constituents	Manufacturer
Ecoflex	PBAT[1] is major component	BASF, Germany
Bicosafe	fully biodegradable copolymers such as PBAT[2] and PBSA[3]	Xinfu Pharmaceutical Co., Ltd.,Zhejiang, China
Biobag Agri	Starch, vegetable oil derivatives, and undisclosed biodegradable synthetic polymers	DuboisAgrinovation, Waterford, Ontario, Canada
Bio-Flex	Blend of PLA[3]and co-polyester	FKuR, Willich, Germany
BioTeloAgri	Strach, vegetable oil derivatives, and undisclosed biodegradable synthetic polymers	DuboisAgrinovation, Waterford, Ontario, Canada
WeedGuard Plus	Cellulosic	Sunshine Paper Co. LLC, Aurora, CO

1 PBAT= poly(butylene adipate-co-terephhalate) 2PBSA=poly(butylene succinate-co-adipate)
3PLA=PolylacticAcid

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- Contributed by C. Miles, D. Hayes, M. Brodhagen, J. Lee, A. Wszelaki, J. Moore-Kucera, R. Wallace, T. Marsh, and D. Inglis. Washington State University, University of Tennessee, Texas Tech University, Western Washington University, and Texas A&M University; USDA SCRI Project No. 2009-02484

2.4 Integrating water resources and water demand to improve drought resilience and build water strategies, Kenya

This chapter is a replication (with small edits) from the following publication: Acacia Water, IRC and Aqua for All, 2014. Integrating water resources and water demand to improve drought resilience and build water strategies.

This text addresses the innovative approach that was developed and tested in the program: by Acacia Water, IRC and Aqua for All.

Introduction

Kenya Arid Lands Disaster Risk Reduction – Water, Sanitation, and Hygiene (KALDRR-WASH), seeks to create resilience against drought in arid and semi-arid lands (ASALs) in a two-year program supported by USAID and The Netherlands. This text addresses the innovative approach that was developed and tested in the program, which uses local participatory water planning to match water sources with water demand. The integrated planning procedures inform strategies for recharging, retaining and reusing (3R) shallow ground water, in order to create stronger water buffers that allow for bridging periods of drought, and include MUS for enhancing food security.

The challenge

The demand for water often exceeds the water available for people and livestock in Kenya's arid and semi-arid land. This problem is only compounded by weak governmental support and the competition for resources (amongst them water) that may potentially lead to an armed conflict in the country. Most water related interventions in the country have a short-term scope and only tackle a single problem, instead of addressing the wider complexity of the problem at play within a community. The benefits are therefore often only short-lived and dwarfed by the remaining problems. Despite knowing periods of severe water scarcity, rainfall in Kenya is actually sufficient to support the livelihood of the population. The gap between availability and demand actually arises from the amount of water lost through surface runoff, flooding and evaporation. A new approach is needed to unlock the potential of the water sources, and to use and manage them in a strategic and sustainable fashion allowing for multiple use services.

Integrated approach for matching water supply and demand

The consortium of Dutch partners has developed an innovative approach that integrates the management of local water resources and services. The potential of water sources and the existing supply infrastructure is measured, while additionally the total water demand and water access challenges are taken into account based on the RIDA framework[13]. This integrated area-based approach overarches all local water uses (domestic, livestock and agriculture), all the local water resources and the relevant local water stakeholders (operators, users and government).

Sanddam, Kalemngorok, Turkana (by Reinier Visser, 2013)

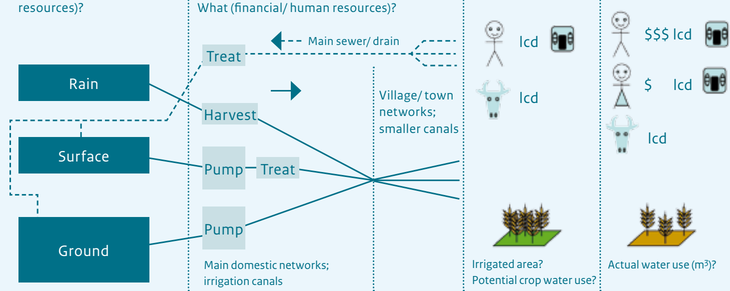
Box : Results provide the following benefits:

- Guiding policy makers, funding organisations and coordinating entities towards determining appropriate interventions to match local water supply with multiple demands in MUS.
- Supporting implementing organisations in identifying technically, environmentally and financially sound options for water supply when applying for funding.
- Supporting local stakeholders to identify and deciding on water supply solutions for managing drought and securing livelihoods.

[13] *Resources, infrastructure, demand and access*

RIDA FRAMEWORK

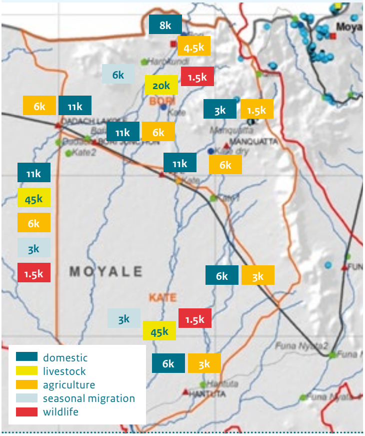
RESOURCES (water resource in space and time)	INFRASTRUCTURE (supply/ treatment capacity)	DEMAND (entitlement/ need)	ACCESS (ACTUAL USE)
How much water in space/ time? What quality? Who manages it? What rules? What (financial/ human resources)?	What infrastructure? What is its condition? Unaccounted for water? What is its capacity (nominal and actual)? Who controls it? What rules? What (financial/ human resources)?	What users? How many users? What demand? What institutions? Legal frameworks?	What subgroups? Periods of scarcity? Coping strategies? Barriers to access?



Source: Moriarty, et al., 2007.

If local stakeholders follow the principles of the RIDA framework, they have the tools to develop a long-term water master plan that matches resources, infrastructure, social context, demand and access. Subsequently an estimate is made of the gaps in supply and demand for the coming ten-year period, based on both field assessment and research. Strategies are subsequently developed to effectively close these gaps by improving the water infrastructure, water governance, capacity development and multiple use water services (MUS). The stakeholders divide the associated responsibilities for coordinating the different strategies of the water master plan. The costs of the project are based on the lifecycle cost analysis of the water services. This approach contributes to a better understanding of overall costs involved including operational costs, maintenance, rehabilitation and the eventual replacement at the end of the lifecycle. This approach equally supports creating consensus, and agreement on the ways of financing each of the interventions.

POTENTIAL FOR WATER BUFFERING: 3R APPROACH IN NORTHERN KENYA



Source: IRC, forthcoming.

The stakeholders select the appropriate recharge, retention and reuse strategies to complement the traditional water sources, like boreholes, in order to increase the amount of useful water. 3R solutions increase the local water chain of and its uses by storing water in shallow aquifers, soil, open water and smaller infrastructures, like tanks and ponds. The ultimate goal is to create secure water buffers that meet the local water demand for each of the multiple uses. When successful, these efforts are translated into tangible results, for example, being better equipped against droughts, increased productivity, food security and improved access to drinking water. 3R interventions and techniques are widely adopted these days. Good examples of this use in ASALs are sand dams, sub-surface dams and water pans.

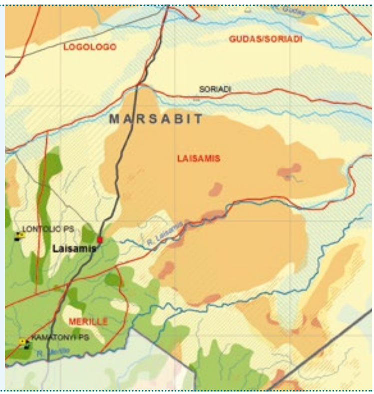
POTENTIAL FOR WATER BUFFERING:
3R APPROACH IN NORTHERN KENYA

The selection of 3R interventions in the programme area is based on the teristics of the natural landscape.
The 3R study assesses the potential to strengthen water resources through recharge, retention and reuse.

The assessment determines the techniques that can be used and the amount of water that can be stored. The potential for water buffering is visualised at a landscape scale through a zone map.

The methodology for selecting 3R interventions, developed and applied for the first time to Kenya's ASALs, is described in a separate publication by Acacia Water.

Detail of a 3R map: The colour zones indicate the kind of 3R intervention that may be possible in the area.



Source: Acacia Water, 2013.

Promising findings and initial successes from the pilots

- In rural areas, only a relatively small portion of the rainfall is required to be stored to meet demands, even in the driest years.
- Local participatory water master planning is a powerful tool for guiding interventions and building drought resilience.
- The methodology can be replicated and scaled up for other areas, and serve as a benchmark for estimating resources and the necessary infrastructure for meeting future demand.
- In Wajir, the participatory planning meeting addressed and neutralised conflicts over water and land. The mapping of the water gaps informed discussions on options for grazing land strategy in both wet and dry seasons. Participants agreed to create new water sources near their homesteads so that conflicts with neighbouring clans who have migrating herds would be avoided.
- In Marsabit, county planners were very positive about using new tools and generating new insights by adopting set priorities.
- In Moyale, stakeholders said that the tools provided demonstrated an excellent opportunity to integrate traditional water management practices, which used to be neglected in most other planning processes.
- In Marsabit, Wajir and Turkana, government representatives recognised the link with Kenyan planning mechanisms and said the new tools would help them translate county plans into tangible actions.

Future direction

The conducted pilot was based on proven approaches that were developed in different contexts but were tailored to the specific needs of ASALs in Kenya. The methodology has to be refined in such a way that it can be replicated and scaled up, for which the following steps need to be taken:

- Integrating the methodology to the government's existing water management planning approach at national and local level.
- Improving interpretation and applicability of the maps (e.g., for irrigation or specific conservation techniques).
- Streamlining participatory processes for small sub-catchments, catchments and/ or county administrative levels.
- Improving planning, by integrating the financial sustainability of water interventions.

Box: RESULTS OF THE INTEGRATED APPROACH IN MOYALE

Kenya's Kate area west of Moyale has a high demand for water but the existing water sources only have limited functionality. Tapping new water sources in grazing lands is likely to result in conflicts over water and pastures. The village is in need of water sources for domestic use that not attract more livestock operations. The survey learned that sand dunes in the nearby mountains had the ability to increase the recharge of existing wells that are used during droughts. This type of intervention contributes directly to the resilience of the local community, without creating conflicts or degrading of the land.

Box: WHAT STAKEHOLDERS SAY ABOUT THE APPROACH

- It makes information available in a country where access to data is difficult and therefore provides a good basis for decisions.
- It makes use of a participatory approach that gives the people ownership over the decisions that are made.
- It integrates sub-sectors such as: water resource management, domestic water, agriculture, livestock, industrial development and wildlife.
- It fits into country policy and strategy frameworks, such as the water management planning guidelines.
- It addresses the MUS requirements of communities.
- It facilitates discussions about technology selection due to the use of maps, which provide insights into the catchment area and its characteristics

Community meeting in Eyrib, Wajir *(Photo credit: Margaret Ombai, 2013)*

Whilst the applied methodology in the KALDRR-WASH pilots needs to mature and developed further, these pilots have demonstrated that this approach helps local communities, leaders and governmental staff to discuss and develop innovative solutions to water related challenges in drought prone areas, which may improve the livelihood of the population. The relatively new nature of this methodology, which entails the implementation of the master plans and the 3R interventions, has just recently started therefore the long-term benefits are not yet apparent.

The Dutch and Kenyan partners will continue to develop, test and expand the approach, methodology and tools in collaboration with ASAL stakeholders.

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2.5 Using floods for irrigation and recharge, Yemen

Introduction

Floodwater is often best stored in shallow aquifers. The cost of storing floodwater in shallow aquifers is minimal compared to the cost of storing surface water reservoirs and groundwater. Storing floodwater this way means very little evaporation loss and allows for the water to be reused immediately or at at preferred time – with no conveyance loss.

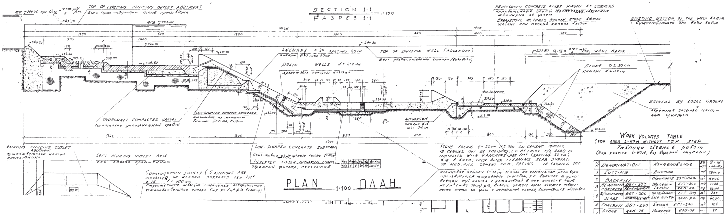
Spate irrigation in Tihama

The capacity to store floodwater varies from aquifer to aquifer.
There is another dimension linking floods and groundwater storage; in cases of intensive groundwater development, effective flood storage capacity in the shallow aquifer will increase, as the top layers are no longer saturated. As a result, floods will either not occur or when they do occur, they will happen less frequently and later in the flood season.

Description

A fine example of combining flood storage, recharge and agriculture are so-called spate irrigation systems. These systems have a longstanding history in arid areas of Pakistan, Iran, North Africa, Sudan and Yemen. Today their use is on the rise in the Horn of Africa and other parts of Africa. Spate irrigation is a prime form of adaptation to extreme climate events. A central feature of spate irrigation is the usage of short duration floods that originate from sporadic rainfall events in highland catchment areas. Floods, lasting anywhere from a few hours to a few days, are diverted from dry riverbeds and allowed to gently spread over the land. As floods usually arrive ahead of the cultivation season, the water is subsequently used for agriculture purposes and soil moisture is often carefully preserved.' Apart from its application as agricultural water, the floodwater is also used for filling water ponds, improving rangelands and tree stands, as well as for recharge. Spate irrigation requires the local construction of diversion structures that are able to withstand flash floods and gently guide large volumes of water over large areas and subsequently slow the erosion process.

In Yemen the spate irrigated areas located on the Red Sea (the Tihama) and the Indian Ocean coastlines are the breadbaskets of the country (see figure 1). Here agriculture is at its most productive. The high water productivity comes from the combined use of floodwater and groundwater, with the spate flows being the main source of recharge. Groundwater in the coastal plains of Yemen is mostly of good quality and as a result can be easily reused. The outcome has been that the spate irrigation systems sustain not only extensive areas of staple crops and a large livestock population, but they have also made it possible to grow large areas of high value horticulture, such as banana and mango orchards. Despite the increase of food security in general, this system has reached a point where groundwater overuse has become a real concern.



The Ras Al Wadi weir with weepholes provided

Techniques used

Most recharge in spate irrigation takes place through the riverbeds. Recharge from flood channels and farming fields is also important but however less significant. There are several ways to promote effective recharge. One is to keep the riverbed protected. Big boulders and stones will slow down the velocity of the floods and will enhance the replenishment of groundwater. A second action is to build structures that slow down the water, these are the regular spate diversion structures. However, in some wadis in Yemen such as Wadi Hadramawt, farmers have even built low weirs across the wadi specifically to increase recharge.

Since the 1980's a number of permanent concrete diversion structures have been built across some of the main ephemeral rivers in coastal Yemen. These structures were constructed to divert the flood flows to land. Although some of them, for instance in Wadi Mawr or Wadi Siham, have inadvertently blocked the subsurface flow as well. These 'cut-off' weirs keyed into the bedrock or clay layers underneath the river. By doing so they had the unintended effect of increasing groundwater levels upstream of the weirs, simultaneously causing hardship for the users downstream.

A better example of a cut-off weir design was used in Wadi Tuban, where openings called 'weepholes' were provided in the main body of the weir. These weepholes allow the subsurface flow to pass through the weir. Substantial flows emerge from them, allowing the downstream wells to continue to function. As a result of the weepholes, it is also possible to construct a relatively light structure. The Wadi Tuban weirs are relatively 'thin', which makes up for a substantial cost saving. If no underdrainage was in place, the weirs would need to be much heavier to prevent them from 'floating away'.

Water emerging from weepholes

Apart from these modern structures, traditional structures like soil, gravel bunds and deflectors also work very well. The traditional structures are typically built for a fraction of the cost of the modern structures. Whereas a system provided with modern concrete headworks may cost 500 to 1800 Euro per ha, traditional structures may cost less than 250 Euro per ha. In many areas they work better as they provide more options to divert floodwater and they do not confuse the water rights. Furthermore, because of their ability to breach in high floods, they are better equipped to keep such heavily silt-laden, and potentially damaging, big floods away from the command area. Smaller floods, however, can be utilized.

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2.6 Groundwater retention weirs, Maharastra, India

Introduction

The Rural Development and Water Conservation Department of the Government of Maharashtra (India) under the Minor Irrigation Programme, Maharashtra (MIP-M), have constructed groundwater retention weirs, or so-called ‘Kolhapur Type Weirs’ (KTW). Weirs are a unique form of irrigation structures as they do not divert water but retain and head up the subsurface flow in the rivers, in order to replenish the wells upstream of the weir. The benefits are vast: they create assured groundwater supply from the wells and improve soil moisture. In this way they contribute to substantially higher yields and enhanced food security, by making it possible to utilize a wider range of crops and benefit from higher crop intensities. As there are no channels to maintain, they do not suffer from the operational problems other irrigation systems have. There are 131 medium-size KTWs recorded in Maharastra, all managed by the Rural Development and Water Conservation

Department. A typical KTW has a command area of some 100 to 250 hectares. On top of the previously mentioned KTW's, there are thousands of smaller groundwater retention weirs under the local government authority.

Bolegaon KTW

A KTW is built across a river in order to store water within the upstream riverbed banks of the weir as well as the adjacent aquifer. For this purpose, a number of piers are constructed on top of the weir. Shutters are placed between these piers, known as 'needles'. This takes place at the end of the monsoon season to store water flowing into the river. These shutters are removed at the start of the monsoon season in June, so that the monsoon flows in the river can freely pass the KTW. It is commonplace to build a bridge on top of the piers for the placement and removal of the shutters, this also allows traffic to cross the river.

Downstream side of Bolegaon KTW *(Photo credit: Olaf Verheijen)*

An example of a KTW is the Bolegaon Weir located in Gangapur Taluka in the Aurangabad District. The climate in Bolegaon is typical for southern India: long dry spells and a fierce southwest monsoon from June to October. Average annual rainfall recorded in the monsoon period is 710 mm predominantly. During August, the middle of the rainy season, there are dry spells that can last up to a fortnight and play havoc with the rain fed crops. A farming population of approximately 2700 people depend on the KTW, they are typically farmers owning less than 2 ha.

In 2004-2005 the Bolegaon KTW was constructed across the Shivna River, which is a branch of the Godavari River. Its length is 92 m and reaches a maximum height of 4.5 m. There are 31 piers constructed on top of the weir. The metal shutters are placed in the openings between the piers towards the end of August in order to catch the receding monsoon flow. With a discharge of at least 6.0 m3/s, it takes no more than two days to fill up the area upstream of the weir. The storage capacity is 1.04 Mm3.

Costs

The KTW had a total production cost of USD 425,000. With a command area of 159 ha, this works out to USD 2,660 per ha. A key advantage of the KTW is that water storage requires no acquisition of land, as the existing riverbed and adjacent aquifer are being utilized. 3 or 4 lift irrigation systems were originally proposed in Boleagon in order to pump the stored water onto the fields located on the left bank of the Shivna River. Farmers themselves indicated that there was no need for implementing these systems, as the seepage from the water stored would sufficiently recharge the already existing wells.

Piers with installed shutters and bridge (upper) Reservoir area upstream of KTW (below) (Photo credit: Olaf Verheijen)

Part of the strategy for constructing the KTW was inviting effective participation from the farmers concerned in the planning, design, construction and management of the irrigation scheme. Upon completing the construction, the responsibility for the operation and maintenance of the newly constructed KTW was formally handed over to the farmers. For the management, operations and maintenance of the KTW a water users association (WUA) was created. It was formally registered and took over responsibility for the KTW in 2005.

The WUA collects an annual irrigation service fee from all landholders irrigating their fields within the command area, this is for operating and maintenance of the KTW. For the 2009-2010 season, the WUA set the fee at INR 1,000 (USD 22) per ha for sugar cane and INR 750 per ha for all other crops. For the 2010/2011 financial year (FY), the WUA proposed to increase the service fee to INR 3,500 (USD 77) per ha so that it can replace the rubber seals of the shutters. In addition, the leasing of fishing rights (INR 15,000 (USD 330)) was generated by the WUA as an additional source of income.

Up till now, the actual maintenance expenditure has been modest: INR 63,000 (USD 1386) was spent during the FY 2008/2009 and INR 53,000 (USD 895) in FY 2009/2010. These expenditures were related mainly to the replacement of the bolts of the shutters. An important advantage is that, contrary to conventional diversion irrigation systems, siltation upstream of the KTW is not a problem. When the shutters are removed from the KTW prior to the onset of the monsoon season, the first floods wash away any silt that has been deposited during the storage of water.

Benefits

The Bolegaon KTW's command area is situated on both banks (although predominantly the left bank) of the Shivna River. The area runs over a total length of over 2.5 km upstream and 1.0 km downstream of the KTW site with a width of approximately of 300 m. It is estimated that in the region of 20% of the total storage, some 1 Mm3, recharges the aquifers through seepage between mid-September and mid-February. This is adequate to safeguard the irrigated agriculture of 109 ha of rabi crop by using groundwater, and makes up the 20% deficit that is not available in the aquifers through natural recharge. The water is lifted by seven newly installed wells and pumps, close to the riverbed, which hold the capacity to irrigate 50 ha of land. These are operated as soon as the riverbed becomes dry. A total of 152 households own land in these areas. According to an inventory, a total of 45 dug wells and a further 9 tube wells were installed in the command area prior to the construction of the KTW. These wells are clustered along the banks of the river and in a designated 'strip' of land away from the river but with a recharge connection from the river. Most farmers use 5.0 to 6.0 HP (electric) pumps to lift groundwater from the wells. Before the KTW was constructed, the wells held water for about 9 months per year until February/March and thereby missed out on the large and vital part of the growth season. Following the construction of the KTW, all wells, apart from three on the right bank, now have water throughout the entire year. A major limitation for operating the wells is that electricity is only available for 8 hours each day.

The WUA has adopted a policy that prohibits the construction of new wells in the command areas, in order to avoid that aquifers are overdrawn and the existing wells run dry. And in order to improve water efficiency even further, a total of 20 farmers have also installed sprinklers over some 50 ha and adopted drip systems on 10 ha in the ICA.


Dug-well (upper) and tube-well (below) in ICA on left bank, India *(Photo credit: Olaf Verheijen)*

Transforming lives

The agro- and socio-economic impact of the construction of the Bolegaon KTW, together with the development of the WUA and the implementation of the agriculture development programme, has brought significant results to the area. Some of the main achievements are listed below in table 2.

First and foremost, major changes have occurred in the cropping pattern, with the area now having increased groundwater security and guaranteed good soil moisture. The range of crops has blossomed, the cropping intensity has gone up and so have the yields derived from the crops. This has had positive effects on contributing to greater food security.

Table 2: Impact of the construction of the Bolegaon KTW, the development of the WUA, and the implementation of the agriculture development programme

Crops	Pre-Project Cropping pattern		Post-Project Cropping Pattern			
	2002/2003		2009/2010		2010/2011	
	Area(ha)	%ICA	Area(ha)	%ICA	Area(ha)	%ICA
Kharif						
Millet	68	43	41	26	10	6
Maize	16	10	7	4	20	13
Pulses	-	-	26	16	-	-
Vegetables	-	-	-	-	2	1
Rabi						
Wheat	-	-	24	15	20	13
Sorghum	24	15	12	8	6	4
Gram	33	21	27	17	1	1
Sunflower	10	6	-	-	-	
Maize	-	-	6	4	-	
Vegetables	-	-	12	8	2	1
Two Seasonal						
Cotton	48	30	48	30	98	62
Chilli	-	-	13	8	2	1
Sugarcane	-	-	11	7	27	17
Horticulture	-	-	6	4	-	-
Ginger	-	-	-	-	2	1
Total	199	125	233	147	188	120

Kharif

The farmers primarily cultivated dry staple crops prior to the construction of the KTW, now five years after building was completed, a much wider range of crops are being harvested. This wider range of crops includes new cash crops like vegetables, chilli, sugar cane and fruit. A number of farmers have also started the cultivation of ginger during the 2010/11 rabi season and the area that produces cotton has increased from 48 ha to some 98 ha.

The cropping intensity increased from 125% in 2002/03 to 147% in 2009/10, but fell to 120% in 2010/11 mainly as a result of the cultivation of long duration crops like sugar cane and cotton.


Cultivation of cotton and sugarcane (left) and ginger (right) in ICA *(Photo credit: Olaf Verheijen)*

Yields have improved considerably thanks to the larger groundwater security, better soil moisture and the agricultural development programme. Maize production, for example, increased from 3.0 t/ ha in 2003-2004 to 5.8 t/ha in 2009-2010. Over the same period the yield of cotton has improved from 0.5-1.0 t/ha to 2.5 t/ha. The data, collected during the 'agro-economic impact assessment 2010', shows that the net return has increased from INR 6,921 (USD 157) per ha in 2003-2004 to INR 36,401 (USD 824) per ha in the 2009¬2010 season. This has led to a 425% spike in farmers' income and a realised return on investment in less than five years. The improvement of soil moisture and availability of irrigation water due to the construction of the KTW have been a deciding factor in the increase of income - as it has allowed farmers to diversify and grow higher value crops and improve their yields. Aside from the benefits the scheme has had on crop production, several other positive influences were pointed out by the Water Users Association:

- 50 to 60 households without land of their own are now employed as daily labourers throughout the year, with wages for female labourers increasing from INR 30 to INR 150 per day.
- Increased access to improved education, with 15 students now attending an English Middle School.
- With more households attending the hospitals in the town of Aurangabad instead of visiting the local health clinic in Gangapur, there is better access to health care
- More families can now afford to consume wheat as part of their daily meals.
- 25 to 30 households have replaced their mud dwellings with constructed brick and mortar housing.
- About 100 households use LPG for cooking instead of the kerosene burners they previously used and most families have a colour television with satellite dish.
- Nearly all households that have land rights in the ICA have acquired a motorcycle in the last five years.
- 15 new tractors were bought by households that own irrigated land in the ICA.
- Dowry's have increased and weddings now take place in wedding halls in urban centres as opposed to village weddings.
- An increased number of households have been able to buy extra cows and buffaloes in order to increase dairy production.

References

- Field survey by Olaf Verheijen

3. Concluding remarks by 'Partners for Water' programme

As implementers of the Dutch Government funded Partners for Water programme, The Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland: RVO) and the Netherlands Water Partnership (NWP) are happy that the Dutch water NGO platform has been able to realise this interesting new edition within the Smart Solutions Series.

Special thanks go out to ICCO who co-funded this edition and to RAIN who are the main contributors of the content of this edition.

to capture a few general concluding remarks about this 7th edition of the Smart Solution Series:

- The sub basin approach as advocated and demonstrated by the 3R consortium contributes tremendously to making the sometimes abstract and 'catch-all' concept of integrated water resource management, more concrete. This offers perspective for concrete application on grass-roots level;
- By virtue of its intrinsic link (and thus acknowledgement of) multiple use water services, the 3R approach clearly demonstrates potential to bridge the gap between drinking water, sanitation and hygiene interventions, integrated water resource management interventions and food security interventions. This results in improved ability to use water in a well-considered manner;
- Most 3R tools and techniques can be considered as 'appropriate' in terms of affordability and technical expertise required by its users/implementers. However, this publication also demonstrates that much knowledge is required by users/implementers for tailor made application of those tools and techniques;
- The Dutch water sector is successful in collaborating on this theme amongst each other but also internationally. This, in combination with its applicability on grass root level, offers a very interesting development oriented product market combination. Such a proposition could be scaled up through public private partnership funding and innovative finance modalities.

We encourage the 3R organisations to further improve and scale up these inspiring water development interventions and to strengthen partnerships with related sectors.

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