Working Paper

Traditional Ecological Knowledge (TEK): Rainwater Harvesting Methods – A Review

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"Few would argue for a complete return to old ways, but it is important to understand the wisdom of TEK and its value of contributing to solving our contemporary ecological problems."
(Menzies 2006, p. 16)

Abstract

Over centuries people in diverse geographical positions relied on rainwater and developed indigenous knowledge and techniques to harvest it. This paper introduces Traditional Ecological Knowledge and Indigenous Knowledge and provides an overview of some of the traditional rainwater harvesting methods by dividing them into two categories: Micro-catchment methods, Macro-catchment and Flood-water methods. Bamboo drip irrigation and rice-fish farming in India are reviewed as case studies. In order to fight environmental degradation of the present and future, it is important to develop holistic and sustainable strategies. For this, it is vital to take into account and to learn from what local people already know and do. There is an urgent need to identify and apply this knowledge for this planet's benefits. These traditional rainwater harvesting practices may have a few challenges to overcome, but they can provide water conservation strategies, especially in vulnerable regions.

Keywords: Traditional Ecological Knowledge, Rain Water Harvesting, Indigenous knowledge, Micro-catchments, Macro-catchments, Flood-water, India.

Table of Content

Introduction

Indigenous knowledge is the continuous development of knowledge over a time period for any given culture or society. It is mostly passed on through oral storytelling traditions by family members from one generation to another. It is not limited to tribes, original dwellers or rural people in a region. Instead, it can be any community which carries traditional knowledge, be it rural or urban, settled or nomadic, indigenous inhabitants or migrants (Mbilinyi et al. 2005). Experience, trials and the adaption to a local environment or changing climatic conditions shaped and adjusted this knowledge and techniques.

Oftentimes, Traditional Ecological Knowledge (TEK) is regarded subdivision of indigenous knowledge, because it is explicit to agriculture and allied sectors (Martin et al. 2010). Berkes et al. (2000) define it as follows:

"We have therefore developed a working definition of Traditional Ecological Knowledge as a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down in generations by cultural transmission, about relationships of living beings (including humans) with one another and with their environment"(Berkes, Colding & Folke 2000, p. 1252).

The emphasis of TEK is the ecological knowledge possessed by indigenous and local cultures extending over a long time period and close engagement with the area's ecosystems. These designs mature over many years according to human needs and can provide tools and expertise for long-term sustainability and resource conservation(Martin et al. 2010).

Kabo-Bah et al.(2008) identify the lack of adequate, clean drinking water as a significant obstruction to economic development and progress. Akpinar Ferrand & Cecunjanin(2014) state that a large percentage of the world population still relies on traditional agricultural practices for their livelihood and agricultural output. In areas threatened by climate change, the re-emergence of ancient low-technology rainwater harvesting practices, almost forgotten over the years, could provide easily adoptable approaches for greater food and water security. This is especially important for arid, semi-arid and tropical wet-dry climatic regions, where water availability is typically seasonal, and hence determines human survival(Akpinar Ferrand & Cecunjanin 2014).

Rainwater harvesting (RWH) can be explained as a process that requires the concentration, collection and storage of rainwater for a number of purposes. This can all be done directly there where the rain falls or in a different area. The water can be used immediately or later. The term rainwater harvesting can refer to an elaborate variety of techniques to collect runoff water by a linked run-off catchment/production area to an individual receiving area (Mbilinyi et al. 2005). However, rainwater harvesting had a higher significance in the past compared to the present (Akpinar Ferrand & Cecunjanin 2014).

Studies (Angelakis 2016; Mbilinyi et al. 2005) indicate that minor dams and runoff prevention measures for agricultural projects are traceable back to early history. This shows that RWH is not a new or recent technology. Communities built and developed indigenous harvesting techniques using rainwater over centuries, as they depended entirely on rainwater. These measures were mainly aimed at improving water availability for agricultural purposes (Mbilinyi et al. 2005). Moreover, every settlement is reliant on an adequate water supply, particularly for areas in arid and semi-arid climate conditions, where water scarcity reaches its maximum in the summer (Angelakis 2016).

Traditional rainwater management techniques change according to the amount of rainfall and its distribution, as well as the type of soil, its depth and landscape it is embedded in. All of these factors influence the methods used, making them site-specific. This leads to a wide variety of different practices such as bunding, pitting, micro-catchments and flood/groundwater harvesting (Malesu, Oduor & Odhiambo 2007).

Other studies (Lucero, Gunn & Scarborough 2011; Pandey et al. 2003) illustrate that the development of ancient and traditional rainwater harvesting technologies were invented due to former climate change events including yearly and multi-decadal fluctuation in rainfall patterns. Hence, some researchers (Lucero, Gunn & Scarborough 2011; Pandey et al. 2003) suggest these methods could be used for climate change adaption. Due to the centralization of water resources as a result of dam construction water had to be transported over extended distances by channelled rivers. This led to a break with long existing RWH traditions, which need to be rediscovered. In particular for tropical regions with a significant number of small-scale farmers, this has proven unsustainable as they face a loss of water access again and again amidst such upgrading (Akpinar Ferrand & Cecunjanin 2014).

Oweis, Hachum & Bruggeman (2004) suggest that West Asia and North African (WANA) regions were the first users of surface runoff and rainwater harvesting methods for agriculture on an expansive level. It is believed that these systems first originated in Iraq approximately 5000 years ago. The practice of rainwater harvesting in India and China goes 4000 years back. Runoff agriculture, also called runoff farming is dated back to the 10th century BC in the Negev Desert. A system in Yemen (dated to 1000 BC) rerouted runoff water to irrigate 20,000 ha to reap agricultural harvests which served up to 300,000 people. In the southern part, sorghum was the main product grown by runoff agriculture. In Pakistan, several ancient systems are still used, such as sailaba and karez. Moreover, North Africa used rainwater harvesting techniques expansively before the Roman era. To this day, the meskat, the jessour and the mgoudwater-harvesting systems are used in Tunisia. For the north-west coast in Egypt, the custom was to use cisterns and wadi-bed runoff farming (Oweis, Hachum & Bruggeman 2004).

It is important to research about TEK as an immediate goal due to the fast loss of language and culture. At the same time, TEK researchers who search for and apply this knowledge should have awareness about the fast changes that already have and are taking place to TEK (Menzies 2006). Martin et al. (2010) argue, that it is crucial to comprehend that outside forces such as colonialism and capitalism have changed TEK by hindering and altering these indigenous practices (Martin et al. 2010). This leads to TEK's researchers seeking knowledge in places within the extent and influence of western science and culture (Laureano 2007).

Traditional rainwater harvesting methods can be found all around the world. This literature review provides an overview of some major traditional rainwater harvesting techniques, categorised under micro and macro-catchments and flood-water methods. Two case studies based in India, in the Northern Himalayas and the North-Eastern hills are discussed. Challenges and limitations of indigenous rainwater harvesting are reviewed with a focus on implementing holistic approaches.

Traditional Rainwater Harvesting Practices around the World

For many millennia, rainwater harvesting has been practiced in most dry areas around the world leading to a large system diversity. However, all RWH systems have these three elements in common (Oweis, Hachum & Bruggeman 2004):

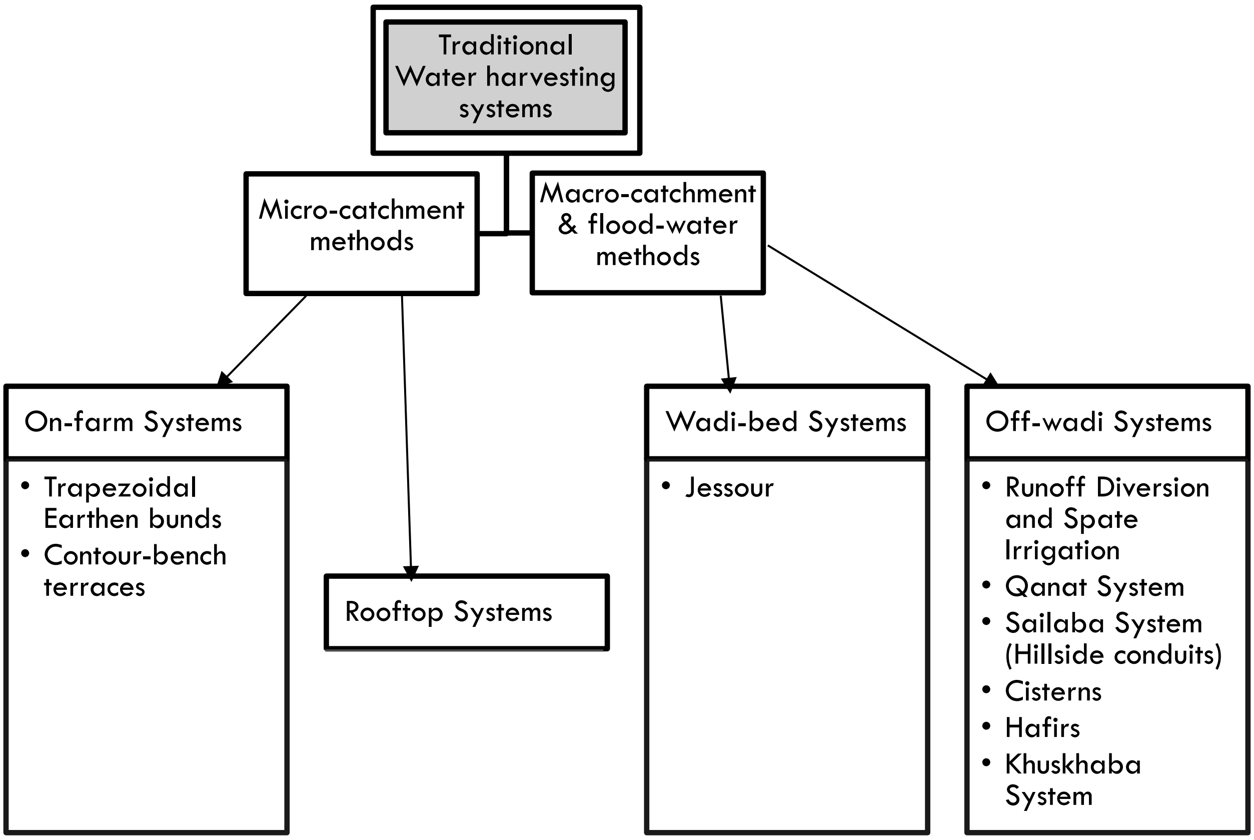
1. The catchment area – this can be as small as a few square metres or as vast as several square kilometres. The topography can vary. Some or all of the rainwater from this part of the land transfers to another area outside its borders.

2. The storage facility – this is where runoff water is collected starting from the time of its collection till the time it needs to be used. Surface reservoirs, subsurface reservoirs, soil, groundwater aquifers are some examples of storage.

3. The target area – this is where the harvested rainwater is used. Usually in agricultural production, the focus is on plants and animals but can also be used for domestic purposes.

In different regions, similar techniques may have different names, while in other regions they may have the same names, but work completely differently. Rainwater harvesting methods can be classified in several ways, mostly according to the storage type or its use, but the most common method is based on its catchment size (Table 1) (Oweis, Hachum & Bruggeman 2004).

Table 1:Categorisation of different traditional water harvesting systems (Oweis, Hachum & Bruggeman 2004)



This overview of ten different RWH systems is sorted into micro and macro catchment areas, and then sub-divided accordingly (Oweis, Hachum & Bruggeman 2004).

Micro-catchment Methods

Collection of surface runoff in a small catchment area over a short distance defines a micro-catchment system. Since these systems have a simple design, replication is easy and adaptable. They mostly do not require a water transport system. Micro-catchment methods can be divided into two sub sections: On-farm and rooftop rainwater harvesting systems (Oweis, Hachum & Bruggeman 2004).

On-farm Systems

This system collects rainfall right where it drops and makes sure that crops effectively use the scarce rainwater. It prevents net runoff from any given cropped area by holding the rainwater and increasing the infiltration time. It is designed to boost infiltration of rainwater into the soil (Mbilinyi et al. 2005). The following are examples of on-farm systems.

Traditional rainwater harvesting has been extensively practiced in several arid and dry semi-arid environments, such as Kenya, Somalia and Sudan, for growing sorghum and millet where annual rainfall was only 150-300 mm. Trapezoidal earthen bunds were constructed with winged walls using hands that held water at least up to a depth of 50 cm, known as teras. Inside this main bund, there were smaller bunds where drought-tolerant crops could be planted in advance. Runoff from beyond the cropped area was collected from the trapezoidal bunds. A further expansion of this technique known as fanya chini was practiced in the Arusha region of Tanzania. Here the soil was scattered down-slope instead of up-slope (Malesu, Oduor & Odhiambo 2007).

The people of Konso, Ethiopia engineered an impressive structure made from local materials to confine debris and silt. Through practice they realised that silt flowed in high velocity water, so they came up with structures to moderate the flow of water, before it reached its final point. The following picture shows contour bench terracing practiced in the steep mountainous regions (Behailu, Pietilä & Katko 2016).

Figure 1:(a) A wooden mesh to sieve debris,(b) fenced pond, (c) preserving ponds from silt by constructing outside terraces, and (d) basins to collect silt coming in through the flood (Behailu, Pietilä & Katko 2016)

They constructed kilometres of bench terraces (which also allowed water to infiltrate through) and planted versatile drought-resistant trees to prevent soil erosion in the steep slopes of Konso. The excess floodwater was collected in ponds specifically made at suitable locations to get maximum agricultural output (Behailu, Pietilä & Katko 2016).

Rooftop Systems

As the term implies, rooftop and courtyard systems are used for collection and storage of rainwater from large buildings, greenhouse, courtyards, houses, and other impermeable objects. The runoff water can pass through a settling basin prior to storage. Water collected through this decentralized method is mostly used for drinking and other household requirements, particularly in rural areas without a central water supply. Such a system is low-cost and provides water for humans and animals in deserted areas. Rooftop systems can also be used for agricultural purposes (Oweis, Hachum & Bruggeman 2004).

Macro-catchment and Flood-water Methods

Oweis, Hachum & Bruggeman (2004) characterised macro-catchment and floodwater-harvesting systems as a comparatively large catchment area that catches runoff water. This mostly consists of natural range land, steppe land or mountainous areas. There are two kinds of macro-catchment systems, depending on the location of the target area compared to the valley (wadi) bed. These are the wadi-bed systems and off-wadi systems (Oweis, Hachum & Bruggeman 2004).

Wadi-Bed Systems

In this system the valley bed is used for water storage. This can be either on the surface by using water flow blockages or inside the soil layers, by slowing the water and letting it infiltrate. In this system, individual farmers or groups of farmers have water flowing through their lands, which makes it a necessity to construct structures, such as small-sized dams or reservoirs. They can use these dams to store runoff water, if an appropriate location exists. An important characteristic of this structure is the construction of a spillway with a certain capacity that is sufficient for high peak flows, which may run through the wadi (Oweis, Hachum & Bruggeman 2004).

In the arid climate of Southern Tunisia, a terraced wadi system is called jessour (Akpinar Ferrand & Cecunjanin 2014). These high, wall-like structures in steep wadis (made up of either Earth or stones, or combined) have a stone spillway in them. As years pass by, these walls stop water and in turn the sediments settle down and accumulate (Oweis, Hachum & Bruggeman 2004). In these settled sediments behind the dikes (known as tabia), figs and olives are irrigated. Other crops may also be planted. The technique is not different from cultivation in the valley bed, other than the fact that it is practiced on steep areas using spillways to get rid of excess water. Jessour are placed in series along the valley, starting from a mountainous catchment (Oweis, Hachum & Bruggeman 2004; Prinz 1996).

Off-Wadi Systems

Off-Wadi systems are those in which harvested rainwater (flowing through the wadi) is altered from its natural route into nearby areas suitable for agriculture using different structures or techniques. This system may be used to collect rainwater from water catchments outside the wadi bed (Oweis, Hachum & Bruggeman 2004; Prinz 1996).

Table 2: Some commonly practiced traditional off-wadi RWH techniques

Runoff Diversion and Spate Irrigation	Spate irrigation is a traditional form of water application to irrigable land by diverting runoff of seasonal flashy floods from the mountainous catchments through dry wadis and transporting it to arable fields (Malesu, Oduor & Odhiambo 2007; Mehari et al. 2008; Mirjat et al. 2011).
Qanat System	Qanat is known by various names such as khettara in Morocco, qanat/kahrez in Central and Eastern Asia including China, and galerias in Spain. It taps into the groundwater (up to 300m deep) to bring it up to the surface, when the gradient of the tunnel crosses with the water table below. Then gravity does the rest of the work without any assistance of power-driven, pumping devices (Behailu, Pietilä & Katko 2016; Oweis, Hachum & Bruggeman 2004).

Sailaba System (Hillside Conduits)	Sailaba systems depend on the natural waterways caused by flooding. Before the runoff water reaches the valley, it is transferred downhill through small channels to planes. These fields are flattened out and enclosed by levees. Using a spillway, extra water can be evacuated to another field that is even further downhill. In this way, all fields are filled up. Then water is let to flow to the valley. This is an ultimate system to make use of runoff water from exposed, scanty vegetated, hilly or mountainous areas (Mathur, Pachico & Jones 2003; Oosterbaan 2009; Oweis, Hachum & Bruggeman 2004).
Cisterns	Cisterns were an early form of rainfall water storage used as reservoirs for rainwater harvesting in arid and semi-arid regions. They were also used to store water for different seasons, transported by conduits. Some were irregularly assembled tanks made of sand and loose rocks, while others were coated with plaster to waterproof them (Angelakis 2016).
Hafirs	Water pans known as hafirs and earth dams/tanks were traditional and fundamental features, with a large water storage capacity for livestock and small scale irrigation in arid and semi-arid lands of Kenya, Somalia, and Southern and Northeastern Uganda. These used to be dug into slightly sloping land to collect runoff water from deviation from drainage basins (Malesu, Oduor & Odhiambo 2007; Oweis, Hachum & Bruggeman 2004)
Khuskhaba	Earthen bunds are built across the land's slope. Rainfall rushes down the incline and is trapped and infiltrated into the soil, supplementing soil moisture, commonly in the valley floors. Part of the land is used for water catchments, while the rest is used for crops. The water runoff from the catchment area is conveyed to the cropped area to enhance yield (Mathur, Pachico & Jones 2003; Oosterbaan 2009).

Rainwater collection, harvesting and storage was the reason for success of past civilizations which include Central America, Southeast Asia and the Middle East. Most of the ancient and traditional RWH technologies in this chapter were established in response to the overall climate of those regions. In these very challenging environmental settings such as the dry-wet, semi-arid and arid climatic regions, people were still able to sustain themselves and thrive (Akpinar Ferrand & Cecunjanin 2014; Lucero, Gunn & Scarborough 2011; Pandey et al. 2003).

Traditional Rainwater Harvesting in India

The Indian subcontinent has a huge variety of impactful and promising rainwater harvesting practices that extend from dry and wet to arid climatic regions. Presently, the widespread application of RWH lacks in this country for reasons such as reduced incentives, old colonial-era policies, rise in urbanisation and groundwater extraction, and huge irrigation projects for producing cereal. However, the value of RWH techniques within a holistic water resource management is now being realized. The interest is growing because of an increased pressure on natural resources due to the large population (Akpinar Ferrand & Cecunjanin 2014).

Agarwal et. al (1997) examined many traditional methods of rainwater harvesting systems developed across India in their book 'Dying Wisdom'. Figure 2 below shows the different ecological regions of India, categorized into 15 ecological regions (Agarwal & Narain 1997).

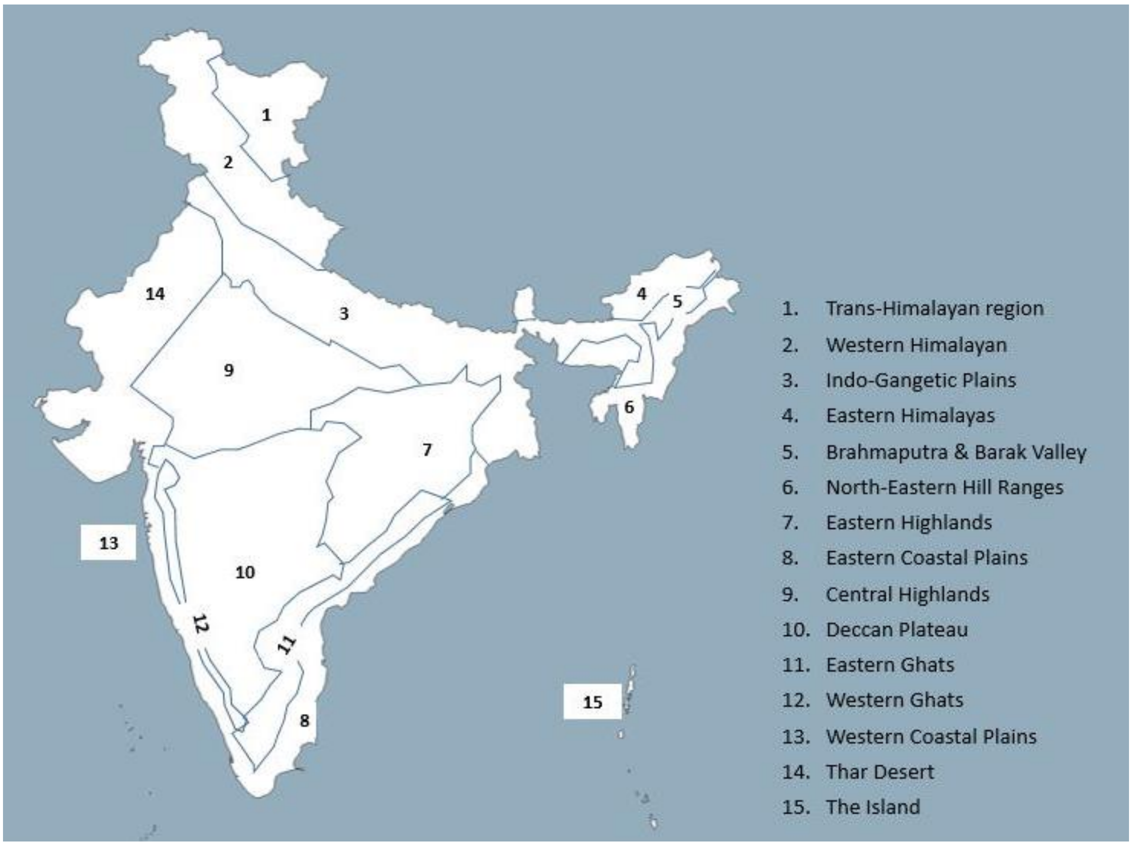


Figure 1: Ecological Regions of India

Each ecological region has its own specific systems, adapted to climate and geography. In this review, two such systems, the 'Rice-Fish irrigation' practices in the Eastern Himalayas and 'Bamboo drip irrigation' in the North-eastern Hills are discussed as case studies.

Integrated Rice-Fish farming in the Eastern Himalayas, India (Case Study)

The Ziro Valley in Arunachal Pradesh (in the Eastern Himalayas) consists of 26 main tribes with 110 sub-tribes. The combined system of growing rice and fish (Aji-ngyii) is what makes Apatani tribes unique, as this is their mode of income and keeps the economic balance for the farmers and their families (Nimachow et al. 2010). Of the annual 1,758 mm of rainfall, 75 % takes place between May and September. After this, a dry winter arrives, followed by March and April, which represent the driest time of the year. The specific kind of irrigation used in this integrated farming approach resembles terrace cultivation, but the difference lies in the fact that it is practiced in valleys, which are only slightly sloped. Over time, the Apatanis developed a technical system for field irrigation, which includes moderately flooded rice fields and contour dams dividing the plots in an elaborate design (Agarwal & Narain 1997).

This multifunctional water management system incorporates land, water and farming systems by providing a barrier against soil erosion, and also helps to conserve irrigation water and paddy-cum fish cultures. Held by bamboos and wooden clips, dykes or bunds (0.6 m to 1.4 m wide and 0.2 to 0.6 m high) are erected in the fields to hold up the water level. To keep the soil as fertile as possible, ploughing is avoided (Nimachow et al. 2010). Millet is also irrigated on dry hilltops as part of dry cultivation (Agarwal & Narain 1997).The figure below shows a flooded rice-fish field.

Figure 3: Rice-Fish Field (Kembangraps 2015)

Rai (2005) and Nimachow et. al (2010) observed that from the end of the harvest until the next plantation, women and men took baskets full of rice husk, pig and chicken droppings, ashes as well as kitchen waste to layer it on to these fields, to preserve soil nutrients. Moreover, a vital source of manure was supplied by letting out household wastewater into the irrigation canals. After harvesting, cattle were allowed to roam freely on the fields, which added to the green manure. Lastly, leachate of the decomposed leaves was gathered using pipes connected to a main canal leading to the plots (Nimachow et al. 2010; Rai 2005). However, according to Agarwal & Narain (1997) oftentimes rainwater transported human, pig and poultry faecal matter into the local water channels which connected to the overall irrigation system (Agarwal & Narain 1997).

Human urine and composted faeces mixed with other items such as wood ash, kitchen and garden waste can meet the potassium and phosphorus needs of plants to enhance the soil structure (Heinonen-Tanski & van Wijk-Sijbesma 2005). According to Jönsson et al. (2004), heavy metals content and other substances such as residual pesticides are usually low in excreta, and depends on the amounts present in consumed products (Jönsson et al. 2004). However, Heinonen-Tanski & van Wijk-Sijbesma (2005) identify that even though fresh urine does not contain many enteric microorganisms, some human pathogen microorganisms or helminth eggs can be found in it. Hence the dosage requirements need to be calculated to avoid health risks. However, a high number of enteric microorganisms (including pathogens) are always contained in human faeces. Due to its hygienic quality and high nutrients, urine is a much more reasonable resource for crop fertilisation. The researchers further argue that in the cultivation of food plants for humans, the urine used to fertilise the fields should not contain any faeces. In case a person is infected, helmith eggs or schistosoma miracidia are able to go into the soil through urination (Heinonen-Tanski & van Wijk-Sijbesma 2005).

People in developing countries in the tropics have a higher chance of infection. Prior to applying human faeces as fertilizer, it must be free from enteric bacteria, viruses, protozoa and helminth eggs which might be high in numbers as mentioned above. To achieve this, composting is the best option, as it helps with the balancing of carbon and nitrogen in case excess of it is present (Heinonen-Tanski & van Wijk-Sijbesma 2005).

To assist the fish, refuge trenches (about 25 - 35 cm) are made, either perpendicularly or irregularly. The dikes in the terraces of varying heights ease the complete drying of the water from rice-fields at an elevation. These water exits made of bamboo screens prevent the fish from escaping. A maximum of 2 - 3 seedlings are sowed at a gap of 20 - 25 cm, hill to hill. After 10 days, fish fries or fingerlings (15 - 20 mm) are stocked at a rate of 2500 ha^{-1}. Chemical fertiliser is not used at all in the rice fields. To fix nitrogen Azolla and Lemna are left to grow. After 3 - 4 months, the fish is harvested (Saikia & Das 2008).

If the pesticide input is not managed correctly, fish farming in irrigated rice fields might cause health risks. For example, in Japan common carp culture in rice fields faced severe setbacks due to pesticide use. Nonetheless, the paddy-fish culture practiced by the Apatani is completely based on organic farming (Nimachow et al. 2010).

Amongst other traditional Indian agro-ecosystems, Apatani agriculture has proved to be extremely proficient, as it has the highest energy efficiency for a rice agro-ecosystem (Agarwal & Narain 1997). Keeping the aim of maximising rice production, organic practices are given utmost importance. From the Apatani Plateau the rice production was roughly calculated as 3,000 - 4,000kg $ha^{-1}y^{-1}$. Total fish produce from this specific system ranged from 300 - 500 kg ha^{-1} $season^{-1}$ without any use of supplements for the fish. The cultivation cost is low, with very little external inputs (Nimachow et al. 2010; Rai 2005; Saikia & Das 2004; Saikia & Das 2008). However, as it is a mono-species culture of common carp, a comparison has been made to Chinese farmers which were able to produce 750 kg ha^{-1}. This means that through combined efforts, there is a prospect for further growth (Saikia & Das 2004).

The Apatani farmers face a number of challenges, including low income. It is important that the government, as well as other social establishments pay attention to this eco-friendly technique. There is a great need to spread awareness among the workers regarding the role of fish as biological controlling agent, conservation of soil quality and recovering and reusing of nutrients. Moreover, educating the local farmers about options such as bank loans and grants for economic stability to be able to adjust to rice-fish culture might play an important step in changing the intentions of a farmer towards sustainable farming practice. Parallel to this, further research on bio-fertiliser, water management and selecting and developing different fish species, instead of mono-culture should be promoted (Saikia & Das 2008).

Bamboo Drip Irrigation in the North-Eastern Hills, India (Case Study)

Bamboo Drip Irrigation is practiced in Meghalaya Hills, one of the seven North-Eastern states in India, which is distinguished by the highest rainfall in the world. With an annual record of about 11500 mm, it is the wettest and dampest place on Earth (Envis Centre, Ministry of Environment & Forest, Govt. of India 2017). This 200 year old method is practiced on topography that consists of extreme slopes and rocks, where using ground channels to redirect water is therefore not a possible(Agarwal & Narain 1997). The Meghalaya hills are home to approximately 3,108 km^2 of bamboo forests of 38 different species (Centre for Science and Environment 2011).

Bamboo has proven to be an eco-friendly and sustainable renewable resource (Envis Centre, Ministry of Environment & Forest, Govt. of India 2017).The mechanism works as follows: 18 - 20 litres of water enter the bamboo pipe network per minute, flow several hundred metres, while reducing to 20 - 80 drops per minute at the final plantation site. It is common to use this intricate bamboo drip system to irrigate betel leaf and black pepper crops that are sown in areca nut or mixed orchards. Only in dry winter seasons irrigation water is needed in this area. The bamboo pipe system is used for this purpose and is readied before the season's arrival (Agarwal & Narain 1997).

From the hilltops, bamboo pipes detour perennial springs to the lower areas, taking advantage of the gravitational force without the need of any energy input. Channels shaped out of bamboo draw out and send water to the plot where it gets divided without any leakage into further subdivisions. Water flows into horizontal pipes is made possible by maneuvering the position of the intake pipes. The end section allows the water to flow near plant roots; this is only possible due to diversion units and reduced channel sections(Agarwal & Narain 1997). These pipelines are 1- 2 m above the ground, held in place by bamboo or wooden standing structures(Singh & Gupta 2002).

The farmers take care of the maintenance themselves (Envis Centre, Ministry of Environment & Forest, Govt. of India 2017). Efforts have been made to bring in modern pipe systems. However, farmers find it difficult and unnecessary to change, due to familiarity with this efficient traditional rainwater harvesting system. New systems have been met with suspicion, as the local farmers neither trust the materials nor the people who supply them (Agarwal & Narain 1997).

Bamboo supply has recently been under danger due to an alarming increase in rodents, gregarious flowering, disease and large-scale extraction. On a positive note, big-scale conservation and protection plans are already in action in many regions, which constitute over 50 % of the total amount of bamboo in India (Envis Centre, Ministry of Environment & Forest, Govt. of India 2017).

Challenges/Limitations

Indigenous knowledge for irrigation and water management developed over many years through practice. These aided communities to cope very well with water shortages, droughts, crops loss, etc. Farmers are able to predict correctly when rainfall will take place and plant their crops accordingly. However, in recent years this has become very difficult due to the change in rainfall patterns. So farmers are changing the crop types to adapt to this change, for example shifting from cocoa cultivation to drought resistant crops such as cassava. Moreover, vegetable farmers are slowly shifting to the river plains to grow crops as they do not receive the required amount of water in their current fields. A major source of money earned previously through cocoa farming supplemented the upkeep of families and helped with getting more agricultural input and in developing their farms (Huntington 2000).

According to Martin et al. (2010), even though this current era is oftentimes cited as the information age, a vast amount of information has been lost due to the disappearance of many cultures. At the beginning of the 20th century, there were more than 6000 languages and cultures, but now half of these have disappeared. 80% out of the remaining languages are now just spoken by a small-scale group of older people. This is worrying because losing a language is connected to a loss of knowledge, beliefs, values and practices that the language carries with it. Hence, the fast loss of language and culture makes it even more crucial that research on TEK is carried out with the aim to respect, preserve and maintain indigenous knowledge (Martin et al. 2010).

Moreover, Menzies (2006) argues that it is well founded that the intentions of the scientists studying TEK is looked upon skeptically. For hundreds of years, design and management methods centered around European science favored over indigenous practices, which have been disregarded, degraded and displaced (Menzies 2006). Hence, TEK researchers should put very clear goals forward for local and indigenous groups to address the justified skepticism. Even though the problems related with a reasonable compensation to indigenous and local groups for TEK are not solved, models are being brought out to recognise and give monetary rewards to indigenous cultures for their contributions (Martin et al. 2010).

A study by Ganguly et al. (2014)demonstrated that the unreliability of rainfall is one of the reasons that leads to rainfall harvesting being criticised. Furthermore, it being able to fulfil the total water requirement as compared to meeting partial water demand is also criticized. Other issues include chemical and microbiological contamination, mosquitoes breeding in stationary water and a fear of inefficient aspects of rainwater harvesting, with an inconvenient investment-income ratio (Ganguly 2014).

It is common belief that rainwater collection systems deliver good quality water without treatment because of the different surfaces used (e.g. Roof tops) as they are separated from usual contamination sources, such as sanitation systems. Even though the roofs are higher than the ground, often dirt, debris and leaves blow into the collection area. Moreover, birds and animals can excrete upon them. Such instances can pollute the water coming into the storage tank, causing a decrease in quality. Table 2 gives a brief overview of the impurities found in rainwater collection systems (Mosley 2005).

Table 3: Rainwater Harvesting Systems Contaminants (Mosley 2005)

Pollutant	**Cause**	**Hazard**
Dust and Ash	The dirt and vegetation around the site.	Moderate: Can be reduced by cleaning the roof and gutter regularly and flushing the water out once.
Pathogenic Bacteria	Bird and animal excreta on the roof and attached to dust	Moderate: Make sure that the bacteria present in dust or in bird feces is minimalised by first flushings.
Heavy Metals	Materials from the dust or rooftops from urban and industrialized area	Low: Unless downwind from an industry or manufacturing processes such as metal smelter and/or strong acid rain.
Other inorganic contaminants (salt from sea spray)	Spray from the sea, certain industrial discharges in air, use of inappropriate tank and/or rooftop surface	Low: Unless very close vicinity to the ocean or downwind from a huge scale industry.
Mosquito Larvae	Eggs laid by mosquitoes in sewer	Moderate: Screen the inlet/entrance to the tank, make sure there are no gaps.

One of the biggest challenges regarding indigenous knowledge is aiming for sustainability by bringing in new technologies and turning a blind eye to the already existing local knowledge. This is not of any use to the people who greatly rely on traditional procedures. Locals who practice conventional harvesting systems since a long time ago, do not just give these up easily to allow for new and modern machinery and techniques. Unless they are involved in the planning and developing of these new techniques and especially if their social constituents are not given weight, in the worst case scenario, traditional people merely stay outsiders and then go back to old sources once the new facilities break down (Behailu, Pietilä & Katko 2016).

Conclusion

This literature review provides an overview of ten indigenous rainwater harvesting techniques in the broader context of Traditional Ecological Knowledge (TEK). These techniques (categorized into micro and macro catchments and flood water methods) have been developed over centuries as efficient measures for adaptation in areas susceptible to climate changes. Rainwater harvesting has provided sustainable measures for irrigation, as well as domestic needs. As shown in this review, rainwater harvesting was given more importance in the past than in the present. One of the most promising regions was the Indian subcontinent, with a vast variety of traditional rainwater harvesting techniques. To cope with issues such as water scarcity, integrated rice-fish farming in the Eastern Himalayas and bamboo drip irrigation in the North-Eastern hills are practiced to date.

Indigenous rainwater harvesting techniques from different geographical areas are influenced by that region's biophysical factors such as layout, soil type and distance from water sources. By considering these factors, GIS could be used to extrapolate these techniques on a broader topographical area which can put a stop to loss of knowledge. Where required, scientific validation can also be done. Other traditional techniques being used even today show many important advantages of rainwater harvesting, such as the rice-fish farming in India. It must be inspected what is more suited for a specific issue with the given conditions.

If reinstated and developed, RWH technologies could secure the water and food conditions of low economy, developing nations as well as climatically susceptible regions of the world. RWH systems can also contribute to an increase in agriculture potential in dry regions. However, this can only be possible if the progress focuses on a holistic approach instead of the conventional one-dimensional approach of concentrating on just one aspect of providing a certain amount of drinking or irrigation water to people.

Moreover, there is a continuous need to provide information and raise awareness for sustainable usage of water resources. Integrating the poorest people will provide water security for forthcoming generations. To improve agriculture and natural resource management it is worthwhile to have farmers with significant amounts of knowledge on traditional RWH systems be able to identify prospective sites for different systems. It is important to come up with models and methodologies that promote indigenous knowledge.

Picture Credits

Figure 1 (p. 6) (a) A wooden mesh to sieve debris, (b) fenced pond, (c) preserving ponds from silt by constructing outside terraces, and (d) basins to collect silt coming in through the flood by Behailu, Pietilä & Katko (2016, p. 8) is licensed under the Creative Commons Attribution 3.0 Unported License <https://creativecommons.org/licenses/by/3.0/>.

Figure 3 (p. 9) Rice-Fish Field by Kembangraps<https://commons.wikimedia.org/wiki/File:Mina_padi_java_Pj_IMG-20150313-WA0004.jpg>is licensed under the Creative Commons Attribution-Share Alike 4.0 International license <https://creativecommons.org/licenses/by-sa/4.0/deed.en>

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