Water conservation & Desert Rehabilitation.

John C. Greenfield.

Emeritus Agricultural Adviser. World Bank.

New Zealand

The dividing line between arid and semi-arid areas is usually a minimum of 250 – 350mm in winter rainfall areas and of 500 mm in summer rainfall areas, though local factors may cause deviations from these figures. Variability of rainfall is the greatest hazard to crop production in the semi-arid regions. In Jordan farmers broadcast wheat on 200-300 mm areas in the hope of getting a crop once-in-three-years – the main reason they were not more successful was that traditionally, they made no attempt to control runoff in order to store moisture in their soils. When this same land was planted in contour furrows using a mulch hoe drill their yields were extraordinarily good, but the contours had to be set each season as they weathered away.

In the desert areas of the Sudan, farming was confined to the Wadis, once again, when the crops were sown in to contour furrows that filled with the meagre rainfall they were very successful – without this system their crops in the wadis failed.

The Wadis themselves presented a problem of moisture conservation and distribution. The farmers did not have the means of constructing banks for 'water harvesting' , or distributing the runoff for the benefit of their crops, yet these wadis offered the best most fertile rainfed soils in their area.

First, let me describe a "Wadi" so we all know what we are talking about.

A **wadi** is a 'dry riverbed' that only contains water during times of heavy rain. It is an area of 'clay accumulation' where over the period of eons the silt and clay fractions have been washed and 'ground' (by the action of animals' hooves) out of the surrounding soil and transported to the 'out-wash plain' leaving the sand behind to form the desert.

The term "Wadi" is very widely found in Arabic place names. Wadis tend to be associated with centres of human population because of the availability of sub-surface water, and the possibility of crop production.

In English the term "Wadi" is sometimes used interchangeably with "oasis", which is correct linguistically, although many geographers and cartographers consider it an inaccurate usage as Oasis's are often the product of a natural water spring. .

Crossing wide wadis at certain times of the year can be very dangerous, because of unexpected flash floods. Each year in Saudi Arabia there are numerous deaths from this cause. Such flash flooding could possibly be controlled by a system of vetiver hedges across the drainage network leading to the Wadi. These hedges would slow the runoff down and spread it out giving it a chance to soak in to the ground, but at the same time slowing down the flow and preventing some of the flash flooding.

Origin of the Wadis:

Wadis may carry runoff from rain resulting from thunderstorms in distant headwater regions. These streams are generally loaded with silt and sand. Intermittent streams carry runoff from springs where ground water intersects the surface. Thus, these streams commonly contain high amounts of dissolved salts and may have a milky or green hue. Of all the technologies and techniques available going back as far as the Iron Age settlers, none served them better than agricultural terracing, which helped to open up a frontier to the farmers 3-4000 years ago. Because of the terraces' erosion inhibiting characteristics and their tendency to control a little runoff and thereby store some soil moisture this technological advance dramatically altered the attractiveness of the country to the incoming agriculturists and increased its carrying capacity as never before, but nothing has changed since then, also due to erosion, burial from over-topping, and natural destruction, these terrace systems have not lasted.

Without the terraces, runoff traditionally, is uncontrolled, and it is this point that I consider VS has a very important part to play in the development of the arid areas. Rock terraces are hard to build, hard to maintain and generally not very effective. Vetiver hedges on the other hand, once established during a wet season are easy to maintain and sustainable.

Soils in the dry regions are characterised by a low content of organic matter, as the result of sparse vegetation producing few residues, however desert soils are usually favourable for plant growth, as a result of limited leaching by rainfall they are usually fairly well supplied with mineral nutrients though these may be in poor balance with one another; – moisture is the limiting factor.

A common characteristic of the arid soils is their lack of stability, and man's intervention usually results in erosion.

Soil Erosion

Surface erosion of soil is caused principally by rainfall dislodging soil particles from a surface. The energy of a single large rainstorm is enough to "splash over 200 metric tons of soil into the air on a single hectare of bare and loose soil. Individual particles can be splashed more than 0.5 m in height and 1.5 m sideways" This concussive soil movement does not become a problem until the rate of rainfall exceeds the rate of infiltration into the soil, and it this infiltration that VS can improve. Once the infiltration, rate is exceeded, water begins running across the surface, picking up the loosened soil particles with the floating organic matter and transporting them down slope. As it moves across the surface, the water forms rills, or gullies, picking up additional sediment as it goes. The sediment in the runoff water acts as an abrasive, tearing up additional sediment as it goes. Steep slopes and soils with low infiltration rates accelerate the process, making these two factors critical to the erosion process. With the use of vetiver hedges, this runoff is slowed down, spread out and given time to sink in to the soil surface, where it is stored as the essential soil moisture for plant growth.

Topography

Topography plays a major role in the water supply of desert vegetation. Water runs off slopes and collects at lower levels, which may therefore receive moisture far in excess of the actual rainfall. The amount received will depend on the size of the actual catchment area, and its

effectiveness will depend on the uniformity of water distribution in the receiving area. This runoff usually concentrates in the narrow beds of wadis, thus the receiving areas will then be very small in relation to the catchment area. Wadis and other depressions usually contain soil which has better water relationships and higher fertility than the surrounding rocky/sandy desert slopes. It has been my experience that once moisture is stored in these soils, it is available over a much longer period than a far greater quantity stored in the humid tropics where drainage and leaching is more active, causing stored moisture to be lost rapidly.

In regions with less than 100 mm of rainfall annually, soil moisture is usually insufficient to maintain even a diffuse type of vegetation. In such an environment, the so-called 'run-off-deserts', most of the vegetation is concentrated in depressions. It is this point that is the key to developing some sort of sustainable production on these wadis – "extend these depressions"- by contour "V" ditching; contour furrowing stabilised with vetiver hedges. All these depressions were doing was containing runoff, what water they could not or did not contain ran off in to the wadi and was lost.

This I have been able to demonstrate in both the Sudan and Jordan – by putting contour furrows in the Sudan at El Obeid for sorghum production, and by planting Olives in Jordan in contour "V" ditches at Irbid. The only problem then was sustainability as vetiver grass was not available. Once the furrows and the hand-dug "V" ditches eroded and filled in, you were back to square one. Fortunately in Jordan, the "V" ditches were made with a road grader and were permanent enough to last giving rise to excellent olive groves. However, using vetiver hedges to protect these systems, sustainable production would be almost assured.

By using vetiver hedges rather than stone barriers or soil berms, across the runoff areas, a total annual precipitation of not more than 50 mm as runoff may provide the equivalent of 500 mm or more of intercepted water behind the hedge, not to mention the collected nutrients from passing animals also contained at the base of the hedge providing natural fertilisation for the sustenance of the hedge.

The high root-to-top ratio of Vetiver grass (*Vetiveria zizanioides*) is a very effective means of adaptation to dry conditions, as under such conditions the growth rate of the roots considerably exceeds that of the shoots, enabling the root system (and possibly the associated micorrhiza)of the plant to obtain its water from a large volume of soil.

Constructing the Components of the Erosion Model a 'Western Technology'

There has been too much measuring of the effects of erosion it is now time we concentrated on controlling soil loss and runoff. In the USA this study assumes that areas with high erosion rates (>50 metric tons/hectare/year) can not be successfully farmed using dryland farming practices without soil and water conservation structures. This in my mind is not the answer. Static measures using constructed contour banks, absorption banks, diversion banks, waterways and low dams are entirely the wrong system to prevent soil loss and runoff. These practices work against rainfed farmers for the following reasons:

- The banks, waterways and dams are constructed of the same soil you are trying to protect from erosion. They erode and eventually breakdown.
- These measures do not last, can be over topped and destroyed by high intensity storms, which we cannot predict.

- As a system they are designed to run the water off the catchment area and direct it to a point of safe discharge, as fast and safely as possible. This is certainly not what rainfed farmers need in an arid area.
- Absorption banks will hold water, but only in the channel of the bank with little effect back up the slope, in no time they silt up and are useless.
- Constructed banks cause water logging in level lands; flooding and breaking small field bunds resulting in poor conservation of soil and water;

A commonly used equation for determining soil loss and runoff, is the Universal Soil Loss Equation (USLE), developed by the United States Department of Agriculture (USDA) as far as I am concerned for practical purposes, this is a total waste of time and an academic nonsense. Nature provides too many unknowns for this equation, what is needed now is action, not further measurement.

The Effect of Heat:-

In arid lands, dryness and high temperatures are generally associated with each other. Because of the high net radiation and the little water that is available for evapotranspiration, resistance to heat by the plant plays a very large role. Vetiver grass has shown a high resistance to heat when grown successfully on Kimberlite in South Africa where the reflected temperature of the black surface can exceed 50 degrees centigrade.

Salinity:-

Salinity is considered to be the greatest environmental threat to desert agriculture and impacts significantly on biodiversity, water supplies, rural towns and infrastructure such as roads.
It is unlikely that the process of salinity can be reversed within current wadi systems. But the vetiver system is a great tool for future research in these areas and has shown remarkable tolerance to saline conditions.

Significance of Moisture Conservation :-

Soil, water, and moisture conservation is an essential factor affecting the success of any agricultural endeavour. This is especially true in desert areas, where it has long been maintained that the introduction of intensive agriculture, including terraces, enabled human penetration into these areas as far back as the Iron Age, nearly four thousand years ago. Though vast expanses of the arid lands are now not cultivated, it would be a mistake to assume that the types of 'natural' vegetation encountered on them today, have not been profoundly affected by Man. This is especially true for desert environments in which the equilibrium between plant cover and environment is most precarious. It should be obvious to us all that the most significant single factor affecting arid land production is "Moisture conservation".

Throughout the arid regions of the world, Man has used stone terraces for centuries to slow down erosion and in an endeavour to conserve moisture. The nature of these remnants of past agricultural intensification is such that a recently built terrace may be identical in form to one built three thousand years ago, Further, in the life of a terrace, construction, destruction, and reconstruction, is a cycle which may be repeated many times. But for thousands of years

attempts at increasing agricultural production depended on static structures to contain runoff and increase moisture conservation. Obviously terraces alone neither work well nor last, but the technology has not been replaced by any other form of soil and moisture conservation to date. This is the first time that another option is being presented – Vetiver hedges or the Vetiver System (VS), as a sustainable means of bringing production back in to these areas.

Curvilinear Farming, Using Vetiver Hedges.

For some obscure reason, man has persevered with "square blocks" as farm or land development areas – Project areas developed in the past by Aid Agencies are always based on "Squares" on a map. There are no squares in Nature, no right angles, no corners, nature doesn't work that way, and neither should we.
In the desert areas of the Sudan where I worked for several years, I was saddened to see the advocation by aid agencies of square blocks as subsistence cropping areas with no attempt at moisture conservation. The result was failed crops with a few plants surviving well in depressions.
The answer is obvious, harvest the desert runoff to the advantage of the crop you are trying to grow. Instead of having a subsistence farm 50m x 50m, producing virtually nothing, why not have a farm 500m long, by 5m wide following a vetiver hedge designed to catch the full benefit of the desert runoff.
In the Sudan I was given an area by FAO that had failed to produce a decent crop in five years. The area was a 100 ha block just South of El Obeid in a 300mm rainfall area. I was told the area had been depleted of nutrients and that was why it produced nothing. It was obvious to me that the problem was total lack on moisture conservation.
I took half the area and contour furrowed the land, the other half was planted as before, just cultivated and the seed broadcast. We dibbled the same seed in to the deep contour furrows. The rains filled each of the furrows to within a centimetre of the top, the water soaked in to the ground, the resulting crop of sorghum was excellent. By comparison, the 50 ha where there had been no attempt at moisture conservation was a total failure.

I consider the Vetiver System has a place in arid and especially semi-arid land development.