VETIVER POTENTIAL
FOR INCREASING GROUNDWATER RECHARGE

B. Deesaeng, J. Pheunda, C. Onarsa and A. Boonsaner
Watershed Research Division, Watershed Conservation and Management Office,
National Park, Wildlife and Plant Conservation Department,
Phaholyothin Rd., Chatuchak, Bangkok, Thailand 10900. E-mail: bmuay@yahoo.com

Abstract

As expected, there were positively benefits given by vetiver hedgerows such as runoff reductions, infiltration improvement and soil moisture enhancement, as well as groundwater recharge increase. The study on vetiver potential for increasing groundwater recharge was conducted at Yom Watershed, Northern Thailand during 2004-05. Three agriculture sites were selected representing longan, maize and soybean cultivations while six runoff plots (4 x 20 m^2) were established within each selected site. Vetiver hedgerows were planted across the slope within three plots while the other three plots were left as control plots. Soil-water content was measured using TDR profile probe which access tubes were installed within each runoff plot. The 8-inch standard rain gages and evaporation pans were also installed at each site to measure rainfall and evaporation. The water balance components were estimated using the integral form of the following equation:

$$P = R_{chg} + R_{off} + ET + \Delta\theta$$

where P is the rainfall; R_{chg} is the deep drainage; R_{off} is the surface runoff; ET is the evapotranspiration; $\Delta\theta$ is the change in soil-water storage for a given profile.

The results showed that runoff accounted for 3-13 % of rainfall at study sites while vetiver hedgerows reduced runoff by 19-56 %. Evapotranspiration, soil-water storage, and deep drainage accounted to be 33-67 %, 0-14 %, and 31-65 % of rainfall respectively. The vetiver hedgerows increased groundwater recharge by as much as 20 %.

Introduction

Up to the present, the world has been encountering critical declining of water availability and quality. Improvement of ground water recharge is, therefore, an alternative way in water resource planning to mitigate insufficient surface water storage as well as decrease losses through violent rainfall (Grimshow, 2000). Generally, groundwater not only supplies water to wells and springs, but also enhances the dry season flow of major river systems (Chomchalow, 2003). Vetiver hedgerows also play a vital role in watershed hydrology and groundwater recharge. Runoff reductions, infiltration improvement, and soil moisture enhancement, including groundwater recharge increase could be expected from the vetiver hedgerows as well. Rainfall runoff is reduced by as much as 70% when vetiver hedgerows are planted across the slope and on the contour. The hedgerow helps to slow down and spread out runoff over a larger area. In particular, the capability of its strong roots in penetrating into hardpans is found significantly helpful in water infiltration and soil moisture improvement, comparing to many other plants (Chomchalow, 2003). This helpful capability is well supported by the experimental works in India where vetiver grass showed significant increase of soil moisture and crop yields (Bharad and Bathkal, 1991; Howeler, 1996; Rao et al., 1998).

In term of groundwater recharge improvement, there is good evidence that vetiver grass technology improves groundwater. The case studies conducted in both high and low rainfall areas of India showed that, within the areas where vetiver hedgerows are located, water levels in wells are higher, springs do not dry up, and small streams run longer into the dry season (Chomchalow, 2003). Furthermore, the research which was conducted in a farm of the University of Akola, India, estimated that water recharge has improved by 30% at the location where vetiver is applied (Vetiver Information Network, 1994). Unfortunately, not many detailed experiments have been carried out so far. This study was attempted to assess vetiver potential for increasing groundwater recharge as well as to report soil and water balance that were taken place in various agricultural sites where the vetiver hedgerows were applied.

Materials and Methods

Study area description

Geographically, the study area is located at Yom Watershed, Northern Thailand where is classified by Koppen as Tropical Savanna (Aw) with mean annual rainfall of 1,210 mm. The wettest month is September and the driest month is January. The mean annual evaporation is about 1,050 mm and the mean relative humidity is 89 %. Hence, mean daily temperature is about 26 ^{o}C while the maximum and minimum temperatures are 39 and 12 ^{o}C.

The soils were derived from shale, phyllite and andesitic tuff. The texture is sandy clay loam to clay with bulk density ranged from 1.02 to 1.53 Mg m^{-3} and the porosity between 42 and 66 %. The saturated hydraulic conductivity ranged from 6.7 x 10^{-5} to 3.6 x 10^{-4} m s^{-1}. The water table at the study area is deeper than 2 m.

As commonly seen throughout the northern region of the country, cash crops such as longan, lychee, rice, maize, soybean onion, etc., are mainly cultivated within the areas even in the headwaters perimeters. The study sites are also abundant with longan (*Dimocarpus longan)*, maize (*Zea mays*) and soybean (*Glycine max*) which have been planted for more than five years. The study was conducted in 2004 as the time when maize and soybean were planted as usual. Six plots were installed in each crop field including the 7-year longan field. In particular, four vetiver hedgerows were planted across the slope in three plots while the rest three plots were left as control plots. Data were collected after the crops were replanted in the following year (May-December 2005) with dense vetiver hedgerows at that time.

Climatic measurement

Manual 8-inch standard rain gages and evaporation pans were installed at each site to measure rainfall and evaporation. An automatic weather station at Yom watershed research station, about 1 km from each study site, also operated throughout the study period.

Runoff

Six runoff plots (4 x 20 m^2) were established within each selected sites; vetiver hedgerows were planted across the slope in three plots while the rest three plots were left as control. Runoff was measured the next day following rainfall events.

Soil-water status

Soil-water content was measured by using TDR profile probe (PR1, Delta-T Devices ltd., UK) that was calibrated on site. Two access tubes were installed at a depth of 1.50 m in

each runoff plot. Weekly measurements took place during June-December 2005.
For each sampling, the readings were taken at 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 130, 150 cm depths.

Soil-water content for 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100, 100-110, 110-130, 130-150 cm layers were determined by multiplying the volumetric soil water values with thickness of soil layer. Soil-water storage for 0-1.50 profile was determined by summing soil water content of each layer within the profile.

Water balance

The water balance components were estimated by applying the integral form of the following equation:

$$P = R_{chg} + R_{off} + ET + \Delta\theta + Li\text{-}Lo \qquad (1)$$

where P is the rainfall; R_{chg} is the deep drainage; R_{off} is the surface runoff; ET is the evapotranspiration; $\Delta\theta$ is the change in soil water storage for a given profile; Li is the lateral inflow and Lo is the lateral outflow. Assuming steady state lateral flow in the sites, Li and Lo cancels out, rearranging, the above equation becomes

$$P = R_{chg} + R_{off} + ET + \Delta\theta \qquad (2)$$

All components have the same units, volume per unit area, expressed as depth (mm).

Estimating Δθ for a given profile

Change in soil water content for a 0-10 cm soil layer, $\theta_{i,10}$ was estimated using;

$$\Delta\theta_{i,10} = \theta_{i+1,10} - \theta_{i,10} \qquad (3)$$

Change in soil water content for 2nd to nth soil layer was calculated using;

$$\Delta\theta_{i,j} = (\theta_{i+1,j} - \theta_{i,j} + \theta_{i+1,j+1} - \theta_{i,j+1})/2 \qquad (4)$$

where θ is the soil water content at ith time and jth depth. The Δθ for the entire soil profile was calculated using;

$$LL\Delta\theta = \sum_{j=2}^{n} \Delta\theta_{i,j} \times \Delta Zj + [\Delta\theta_{i,10} \times 100] \qquad (5)$$

where *n* is the number of soil layers taken here as 13; Δzj is the thickness of jth layer.

Estimating crop ET

The rate of water used by a crop under field conditions can be estimated by following the method as described in Smajstrla et al. (2000):

- Calculating potential evapotranspiration (ETp) by multiplying rate of evaporation from the evaporation pan with pan coefficient (Kpan), that is approximately 0.7 for Thailand (Chankaew, 1996).

- Calculating crop ET by multiplying ETp with a crop water use coefficient (Kc) for each specific crop. In this study, average Kc for longan, maize, soybean and vetiver are 1.99, 1.14, 1.10 and 0.92 respectively (Irrigation Water Use Research Group, 2006).

Estimating deep drainage

The estimated values of ET, $\Delta\theta$ were then used to calculate deep drainage (R_{chg}) by using equation 2. If the solution was found to be positive, this amount was allocated to groundwater recharge. On the contrary, if the solution was negative, it would be interpreted that there was no drainage.

Results and discussion

Climatic conditions

In 2005, the rainfall was over the annual average with 1,225 mm recorded. September was the wettest month while the driest months were January and February with no rain detected (Figure 1). The evaporation was also over the annual average, with 1,758 mm recorded. Hence, rainfall and evaporation were measured at the study sites in the rainy season till the end of the year (May to December). The accumulative rainfall during the experimental period at three study sites was 1,043, 967, and 1,242 mm at longan, maize, and soybean cultivation sites respectively. Meanwhile, the accumulative evaporation was 424, 452, and 474 mm at longan, maize, and soybean cultivation sites respectively.

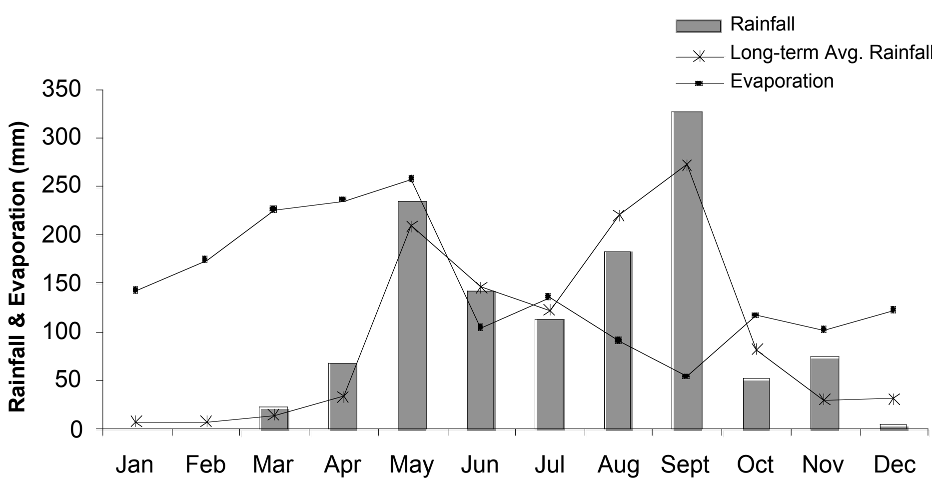

Figure 1: Rainfall and evaporation at Yom Watershed Research Station in 2005

Soil-water status

Average soil-water content data as functions of soil depth during experimental period are displayed in Figure 2. At longan and soybean cultivation sites, the plots where vetiver hedgerows were applied showed higher soil-water contents than the control plots, except at the maize cultivation site. In almost all plots, soil water contents at 10 and 70 cm depth were lower than those at all other depths. However, at a depth of deeper than 100 cm, soil-water contents showed little change during the experimental period.

Soil-water storage for 0-1.50 m profile for experimental plots is presented in Figure 3. At each site, there was evidence of higher soil water-storage content in the plots where vetiver hedgerows were applied when compared to the control plots, with few exceptions in maize cultivation site. This result can be explained by the fact that vetiver hedgerows may help to reduce runoff by diverting it perpendicularly along the contour hedgerows as well as allowing much smaller amounts to pass through, while other amounts were seeped and retained by soils (Land Development Department, 1998; Chomchalow, 2003).

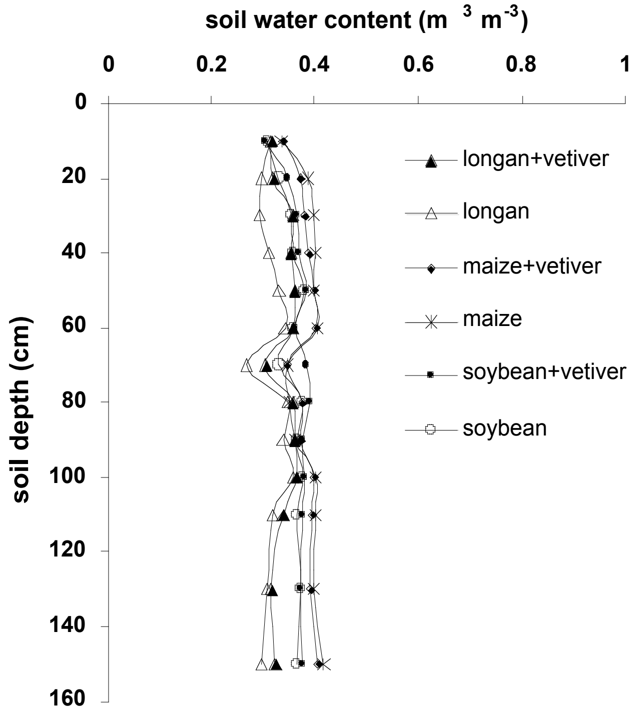

Figure 2: Average soil water contents along the 150 cm-profile of longan, maize and soybean plots and their vetiver hedgerows applied plots during the experimental period

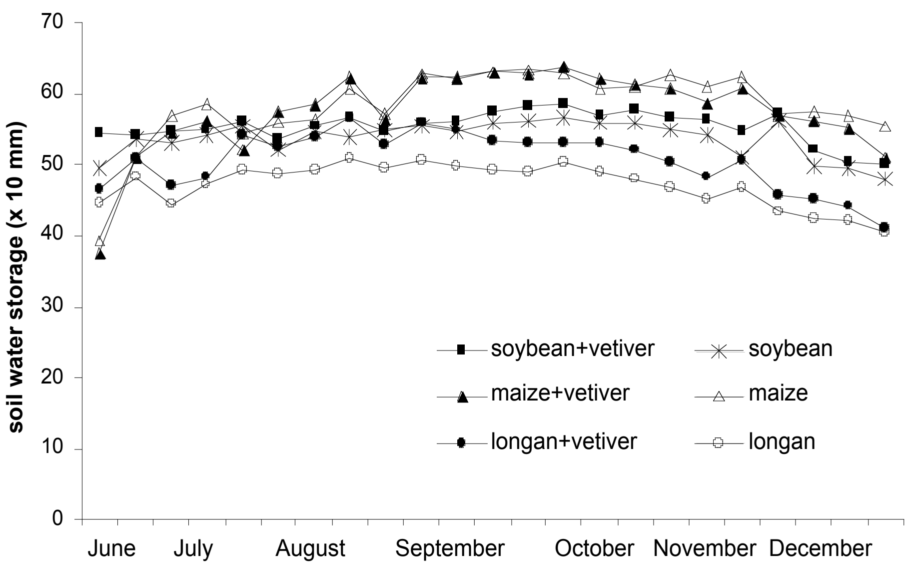

Figure 3: Soil-water storage of 1.50 m profile for longan, maize and soybean plots and their vetiver hedgerows applied plots during the experimental period

Soil-water storage in maize cultivation site was found to be greater than longan and soybean cultivation sites. This result can be explained by the fact that, because of the soil texture of maize cultivation site which is clay, the soil water storage capacity of this site is higher than the rests which have courser texture (Don Scott, 2000; Ministry of Agriculture, Food and Fisheries, 2002).

Runoff

The average accumulated water loss by runoff at longan, maize, and soybean with vetiver hedgerows applied plots compared to control plots were 34.2:57.7 mm, 55.2:125.3 mm, and 31.4: 38.9 mm respectively (Figure 4). At all sites, the plots where vetiver hedgerows were applied showed less water loss compared to the control plots. The vetiver hedgerows were found to reduce runoff in longan, maize and soybean cultivation sites by 41, 56 and 19 % respectively. This result was harmonious with a mass of information, indicating that vetiver grass technology is one of the most effective means of reducing soil and water erosion, such as the finding of Inthapan et al. (1999), Rao et al. (1998), LongJiang (1997), Truong (1997), Howeler (1996), Bharad and Bathkal (1991), Kon and Lim (1991). Agreement among those works shows that water loss by runoff can possibly be reduced up to 70 % when vetiver hedgerows are planted across cultivated slopes. This kind of benefit can be sustained year after year as long as the hedgerows are maintained (Grimshaw, 2000).

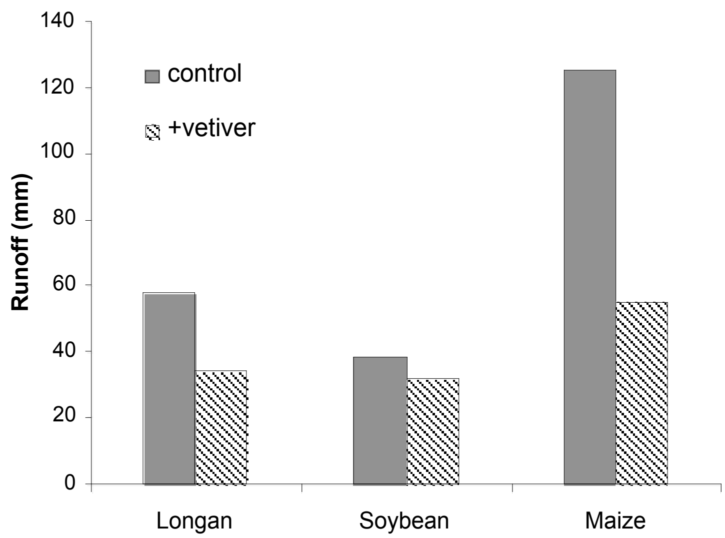

Figure 4: Accumulative runoff from longan, soybean and maize cultivation sites during the experimental period

Water balance

The accumulative evapotranspiration for longan, maize and soybean plots were 666.9, 404.7 and 408.1 mm compared to 697.7, 437.3 and 442.3 mm of the plots where vetiver hedgerows were applied. However, the plots with vetiver hedgerows revealed higher accumulative evapotranspiration than the control plots. The reason may come from the fact that intercrops can withdraw more water as evapotanspiration than their sole crops (Walker and Ogindo, 2002).

Each component of the water balance equation (2) for the experimental period is presented in Table 1. The water used by crops accounted for 33-67%, soil-water storage accounted for 0-14% of rainfall and runoff accounted for 3-13% of rainfall. Amount of rainfall drained to groundwater recharge was quite high (31-65 %) due to the recharge season (rainy season) that almost rainfall amount was input to the study sites and infiltrated into the soils while the excess water run off. However, rainfall is found to be far exceeding evapotranspiration during this period which may cause more excessive soil-water contentthan the soil can store. Soil-water would subsequently be drained freely from the soil profile through gravity. In particular, sandy soils may be capable of draining soil-water within a few hours compared to few days in the case of fine texture soils (Ministry of Agriculture, Food and Fisheries, 2002). This hypothesis is well supported by the result of this study that soil-water storage and Δθ at maize cultivation site, where contains clay soils, were found to be greater than those of the rest sites.

Comparing to the control plots, the maize plots where vetiver hedgerows were applied showed higher recharge values with 20 % increased groundwater recharge. Meanwhile, there were no differences in recharge values found between control and vetiver hedgerows applied plots at longan and soybean cultivation sites.

Table 1 Component of the water balance equation at each site for the rainy season of 2005

Study sites		Rainfall	Evapotranspiration		Runoff		Δθ		Recharge	
sites	plots	(mm)	(mm)	(%)	(mm)	(%)	(mm)	(%)	(mm)	(%)
Longan	control	1043.2	666.9	63.9	57.7	5.5	-30.0	-	348.6	33.4
	+vetiver		697.7	66.9	34.2	3.3	-36.3	-	347.7	33.3
Maize	control	967.4	404.7	41.8	125.3	12.9	139.4	14.4	298.0	30.8
	+vetiver		437.3	45.2	55.2	5.7	116.9	12.1	357.9	37.0
Soybean	control	1242.2	408.1	32.9	38.9	3.1	-9.0	-	804.2	64.7
	+vetiver		442.3	35.6	31.4	2.5	-29.4	-	798.0	64.2

Conclusion

Vetiver hedgerows planted across cultivated slopes at Yom Watershed, Northern, Thailand were found to increase water stored in soil profile while reducing 19-56% of water loss by runoff. Vetiver can reduce surplus runoff by diverting it perpendicularly along the contour hedgerows and allowing smaller amounts to pass through, while other amounts are seeped through the soil and retained by soil profile. In the cropping season, the major proportion of rainfall amount was used by crops and evapotranspiration has greatly affected the water balance. Vetiver hedgerows acted as intercrops that withdrew more water compared to the sole crop. Thus, the water output as deep drainage was not obviously enhanced at high evapotranspiration field. The finding is brought to be the light conclusion that, with fine soils, low soil hydraulic conductivity, and high runoff, vetiver hedgerows could increase groundwater recharge up to 20 %.

Recommendation deriving from this study is that, within the headwaters areas which are normally high slope, vetiver hedgerows can be used as an effective conservation treatment in agricultural practices. The potentials of vetiver hedgerows in holding water, reducing runoff and increasing groundwater recharge are, therefore, the ability to help watershed to store and provide water properly in quantity and timing. This may be an alternative way in watershed conservation that is similar to the function as provided by natural forest.

Acknowledgement

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