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# Conservation of soil, water and nutrients in surface runoff using riparian plant species

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**Abstract**

Three riparian plant species *viz. Cynodon dactylon* (L.) Pers., *Saccharum bengalensis* Retz. and *Parthenium hysterophorus* L. were selected from the riparian zone of Kali river at Aligarh to conduct the surface runoff experiment to compare their conservation efficiencies for soil, water and nutrients (phosphorus and nitrogen). Experimental plots were prepared on artificial slopes in botanical garden and on natural slopes on study site. Selected riparian plant species showed the range of conservation values for soil and water from 47.11 to 95.22% and 44.06 to 72.50%, respectively on artificial slope and from 44.53 to 95.33% and 48.36 to 73.15%, respectively on natural slope. Conservation values for phosphorus and nitrogen ranged from 40.83 to 88.89% and 59.78 to 82.22%, respectively on artificial slope and from 50.01 to 90.16% and 68.07 to 85.62%, respectively on natural slope. It was observed that *Cynodon dactylon* was the most efficient riparian species in conservation of soil, water and nutrients in surface runoff.

**Key words**

Riparian, Conservation efficiency, Runoff experiment

## Introduction

The term riparian is derived from the Latin word *riparius* that means stream bank. The term "riparian" was initially used in the United States in the early 1800 as a legal term (Ortega Klett, 2002). It described a landowner's property adjacent to a stream or river. Riparian areas are ecosystems that occur along watercourses or water bodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. Riparian ecosystems occupy the transitional area between the terrestrial and aquatic ecosystems. Typical examples would include flood plains, stream banks and lake shores (USDA-NRCS, 2005). Riparian corridor vegetation or lack thereof, affects many elements of water quality (Michael *et al.*, 2010). The four most important water quality components affected by the riparian corridor are nutrient loading, sediment loading, water temperature and dissolved oxygen levels in the water.

Riparian zone that are vegetated or covered with local, unmoved grasses not used for grazing can serve as a buffer for the stream by trapping sediment and pollutants carried in surface runoff before they enter the stream (US ACE, 1991). A vegetated riparian zone can also intercept and retain nutrients, such as phosphorus and nitrogen and help keep the stream's food web and algal growth in balance (Daniels and Gilliam, 1996). The buffering effects of riparian zone are sometimes limited by gullies that allow runoff to bypass the riparian zone, robbing it of potential nutrient filtering opportunities. Bishop *et al.* (2004) argued that the particular role of riparian soil is to set the stream water chemistry, since this is the last soil in contact with the water before it becomes runoff. Factors such as soil type, vegetation, slope and others all can affect the buffering capability of riparian corridors (Raju *et al.*, 1992; Srivastava, 2007).

The river banks experience frequent abiotic and biotic stresses *viz.* erosion, flooding, silting, agricultural practices, grazing, scraping and a variety of anthropogenic activities such as washing, bathing, defecating, sewage disposal and using of banks as cremation ground *etc.* (May *et al.*, 1997; Azous *et al.,* 2000). These all stresses lead to partial or complete loss of native herbaceous vegetation (Shafroth *et al.,* 2002). Riparian habitats experience rapid change in nutrient input, storage and outflows of soil, receiving and dispersal of seeds and propagules of far off places and a variety of allogenic forces. The depletion of natural vegetational cover leads to erosion of soil and river meandering. Natural vegetation at banks acts as breakers in regulating the flow of nutrients, water and silt across it to the river from the upland (Fennessy and Cronk, 1997; Lowrance, 1998; Naiman *et al.,* 2002; Srivastava, 2007). Herbaceous vegetation can check surface run-off more effectively on sloping river banks. The role of some riparian herbs in soil and water conservation was previously studied by Raju *et al.* (1992, 1996), Ambasht and Ambasht (2003), Srivastava (2007), Srivastava *et al.* (2010). The losses of nutrients through soil erosion by means of surface run-off constitute the most important means of loss of direct plant nutrients from the riparian lands. The biological productivity of receiving waters is determined by movement of nutrients such as nitrogen and phosphorus in surface run-off.

This paper deals with the conservation efficiency of dominant riparian plant species in reducing amount of run-off water, soil erosion and movement of nutrients through soil and water down the artificial and natural slopes.

## Materials and Methods

Three plant species were selected from riparian zone for conservation studies on the basis of importance value index *viz. Cynodon dactylon* (L.) Pers., *Saccharum bengalensis* Retz. and *Parthenium hysterophorus* L. Artificial slants were prepared in the Botanical Garden of Department of Botany, D.S. College, Aligarh (India). A total of four slanting plots of 1 x 3m dimension each were prepared having 15$^{o}$ slopes because the study site have the mean value of 15$^{o}$ slope in its riparian zone. Likewise 4 plots were also prepared on the natural slopes of study site on the right bank of Kali river. Each of the selected three plant species was planted separately in each plot in their propagule form and the 4$^{th}$ plot was left bare and unvegetated. The same experimental set was also prepared in the plots prepared at study site. Each plot except bare plot showed different vegetation cover due to different growth patterns of the planted species. At the lower end of each plot a polythene sheet was laid down to form a collection area in which runoff water and eroded soil used to collect during and after artificial showering in the experimental process. The experiment was started after 45 days of plantation when the canopy cover was sufficient enough to cover the plot adequately. For artificial showering, 50 l of water was sprayed from a multiporal nozzel at the rate of 10 cm hr$^{-1}$ rain intensity from 1.0 m height. This was done for 30 min at every 15 days interval for three times. The run-off water and the eroded soil were deposited in reservoirs from each of the vegetated and bare plot. Amount of runoff water collected in the reservoir were measured. To prevent water loss by evaporation, sampling of run-off water was done immediately. Eroded soils were collected and oven dried at 85$^{o}$C for 30-36 hrs and weighed and then passed through 0.5 mm sieve before analysis.

**Analysis of nutrient:** Soil phosphorus exists in various chemical forms, including inorganic phosphorus (Pi) and organic phosphorus (Po), which differ widely in their behavior and fate in soils (Turner *et al*., 2003a, 2003b; Hansen *et al*., 2004). Phosphorus was determined in the form of inorganic and organic phosphorus. In runoff water it was analysed by ammonium molybdate – ascorbic acid method (APHA, 1998) and the soluble reactive phosphorus (Inorganic) and soluble unreactive phosphorus (organic) were estimated. In eroded soil phosphorus was determined by Olsen's method (1954).

Amount of nitrogen in runoff water and eroded soil were estimated in the form of ammonium nitrogen and nitrate nitrogen by the methods given by Jackson (1967). In runoff water, the ammonium nitrogen was determined colorimetrically by phenol nitroprusside solution method. Nitrate nitrogen was determined by phenol disulphonic acid method. In eroded soil, ammonium nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956). Micro-kjeldahl method (Peach and Tracey, 1956; Misra, 1968) was used to estimate total and nitrate nitrogen.

Conservation value (Cv) of each of the three species for soil water and nutrients was calculated using the formula given by Ambasht (1970).

$$Cv = 100 - \left(\frac{Sp}{So} x100\right)$$

Cv = Conservation value
Sp = Amount of soil/water/nutrient washed from vegetated plots.
So = Amount of soil/water/nutrient washed from bare plot under identical erosional pressures.

## Results and Discussion

**Soil and water conservation:** Results are given in Table 1. As the 50 l of water were sprayed on each artificial plot, the maximum amount of surface run-off (34.50 l) was recorded on bare plot. Likewise the maximum amount of eroded soil (1725.0 g) was also collected from the bare plot. The minimum amount of water (9.5 l) and soil loss (82.50 g) were recorded in the plot vegetated with *Cynodon dactylon.* The conservation values of *Cynodon dactylon* for water and soil were 72.50 and 95.22%, respectively. Water (12.10 l) and soil(120.50 g) were lost as surface runoff in the plot vegetated with *S. bengalensis*. Conservation values were 64.93 and 93.02% for water and soil, respectively. Plot vegetated with *Parthenium hysterophorus* showed 19.3 l of water and 912.40 g soil as runoff. It showed the conservation values of 44.06 and 47.11%, respectively for water and soil conservation.

At the study site also the bare plot showed the maximum water (33.50 l) and soil loss (1825.0 g). Here also the *Cynodon dactylon* proved to be most efficient in soil and water conservation. It showed minimum water (9.0 l) and soil loss (85.40 g) through surface run-off. Conservation efficiencies were 73.15 and 95.33%, respectively for water and soil. *S. bengalensis* was the next efficient plant species and showed 12.5 l of water and 140.50 g soil as

**Table - 1:** Water and soil runoff quantities and conservation values (Cv) of the three selected riparian species grown on slopes prepared in the Botanical Garden and on study site

| Plot | Plant species | On artificial slopes in garden | | | | On natural slopes on study site | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Water runoff (l) | Cv for water (%) | Soil loss (g) | Cv for soil (%) | Water runoff (l) | Cv for water (%) | Soil loss (g) | Cv for soil (%) |
| 1. | *C. dactylon* | 9.5± 0.5 | 72.50 | 82.50± 2 | 95.22 | 9.0± 0.5 | 73.15 | 85.40± 2 | 95.33 |
| 2. | *S. bengalensis* | 12.1± 0.5 | 64.93 | 120.50± 3 | 93.02 | 12.5±0.5 | 62.69 | 140.50± 3 | 92.33 |
| 3. | *P. hysterophorus* | 19.3± 1 | 44.06 | 912.40± 5 | 47.11 | 17.3± 1 | 48.36 | 1012.40± 10 | 44.53 |
| 4. | Bare (control) | 34.5± 2 | — | 1725.0± 10 | — | 33.5± 2 | — | 1825.0± 10 | — |

Values are mean+SD

**Table - 2:** Concentration of phosphorus present in runoff water and eroded soil from different vegetated and bare plots on slopes prepared in the garden and on study site

| Variables | On artificial slopes in garden | | | | On natural slopes on study site | | | |
|---|---|---|---|---|---|---|---|---|
| | Bare | *C. dactylon* | *S. bengalensis* | *P. hysterophorus* | Bare | *C. dactylon* | *S. bengalensis* | *P. hysterophorus* |
| Total soluble phosphorus water borne (mg $l^{-1}$) | 0.72±.02 | 0.58±.02 | 0.65±.02 | 0.60±.03 | 0.76±.02 | 0.56±.03 | 0.61±.03 | 0.67±.02 |
| Total phosphorus sediment bound (µg $g^{-1}$) | 23.4±.3 | 21.1±.3 | 28.4±.2 | 29.6±.3 | 21.5±.2 | 15.6±.2 | 18.0±.1 | 20.5±.2 |
| Inorganic phosphorus water borne (mg $l^{-1}$) | 0.29±.01 | 0.27±.03 | 0.29±.02 | 0.28±.03 | 0.33±.03 | 0.25±.01 | 0.30±.02 | 0.32±.02 |
| Inorganic phosphorus sediment bound (µg $g^{-1}$) | 12.8±.3 | 13.1±.1 | 18.0±.2 | 17.6±.3 | 15.0±.1 | 10.5±.1 | 11.5±.1 | 14.5±.2 |
| Organic phosphorus water borne (mg $l^{-1}$) | 0.43±.02 | 0.31±.03 | 0.36±.02 | 0.32±.02 | 0.43±.02 | 0.31±.02 | 0.31±.01 | 0.35±.03 |
| Organic phosphorus sediment bound (µg $g^{-1}$) | 9.6±.4 | 8.0±.3 | 10.4±.2 | 12.0±.2 | 6.5±.1 | 5.1±.2 | 7.5±.2 | 6.5±.1 |

Values are mean+SD

runoff. Conservation values were 62.69 and 92.33%, respectively for water and soil. *Parthenium hysterophorus* showed 17.3 l and 1012.40 g soil as runoff. Conservation values for water and soil were 48.36 and 44.53%, respectively.

It was observed and apparent that artificial showering produced heavy impact of water drops on each plot. On bare plot the impact caused heavy erosion resulting in heavy deposition of soil in the collection area down the slope due to detaching and transporting vulnerable soil directly by means of rain splash. Artificial rain drops also broke the clump of soil into finer particles, which easily moved away by unhindered flowing water. When the surface runoff occurred on the vegetated plots, the vegetation intercepted the water drops and formed local hindrance to free and fast movement of water, thereby provided enough time to the soil to absorb water (Raju *et al.*, 1992). On the bare plot, the unvegetated condition allowed the water to move down the slope more strongly forming narrow channels in the plot. Because *Cynodon dactylon* had more dense vegetal covering on the plot it ably reduced the free flow of water and drastically reduced soil erosion. It also binds soil more perfectly and didn't allow the soil to move along the slope with the surface runoff. *S. bengalensis* also reduced the soil erosion in runoff because it also binds the soil comfortably. *P. hysterophorus* did not had adventitious roots therefore observed as least efficient plant species in reducing soil erosion down the slope.

During and after rain much of the water runs down into the river from the sloping riparian land. If the riparian slopes have thick vegetation cover then the surface runoff would be reduced and infiltration would be maximized in the soil.

Bare plot showed loss of highest amount of water through surface runoff because there was no vegetal cover to make slower the movement of water which rendered less time for infiltration thereby higher amount as surface runoff. Vegetal cover on other plots provided sufficient time to infiltrate and thus lowered loss of water during artificial showering. Plot vegetated with *Cynodon dactylon* showed highest amount of infiltrated water during experiment because dense vegetal cover slowed the movement of falling water.

**Table - 3:** Concentration of nitrogen present in runoff water and eroded soil from different vegetated and bare plots on slopes prepared in the garden and on study site

| Variables | On artificial slopes in garden | | | | On natural slopes on study site | | | |
|---|---|---|---|---|---|---|---|---|
| | Bare | *C. dactylon* | *S. bengalensis* | *P. hysterophorus* | Bare | *C. dactylon* | *S. bengalensis* | *P. hysterophorus* |
| Total soluble nitrogen (mg $l^{-1}$) | 3.45±.01 | 2.34 ±.01 | 2.42 ±.02 | 2.51 ±.02 | 4.16±.03 | 2.35±.03 | 2.37±.02 | 2.52±.02 |
| Total soil bound nitrogen (µg $g^{-1}$) | 4.12±.01 | 2.48 ±.02 | 2.67 ±.02 | 3.70 ±.01 | 5.05±.04 | 2.66±.03 | 2.71±.03 | 3.81±.03 |
| Soluble ammonium nitrogen (mg $l^{-1}$) | 3.21±.02 | 2.19 ±.02 | 2.15 ±.01 | 2.21 ±.03 | 3.72±.02 | 2.14±.02 | 2.13±.02 | 2.18±.02 |
| Soil bound ammonium nitrogen (µg $g^{-1}$) | 0.14±.01 | 0.11 ±.01 | 0.09 ±.01 | 0.12 ±.01 | 0.17±.01 | 0.13±.01 | 0.10±.01 | 0.15±.01 |
| Soluble nitrate nitrogen (mg $l^{-1}$) | 0.24±.01 | 0.15 ±.01 | 0.27 ±.01 | 0.30 ±.01 | 0.44±.02 | 0.21±.02 | 0.24±.01 | 0.34±.01 |
| Soil bound nitrogen (µg $g^{-1}$) | 3.98±.02 | 2.33 ±.02 | 2.58 ±.02 | 3.58 ±.02 | 4.88±.04 | 2.52±.03 | 2.61±.02 | 3.66±.04 |

Values are mean±SD

**Table - 4:** Conservation values (Cv) of three selected riparian species for phosphorus and nitrogen at both artificial and natural slopes

| Plant species | On artificial slopes in garden | | | | On natural slopes on study site | | | |
|---|---|---|---|---|---|---|---|---|
| | Total phosphorus flown with water and soil (mg) | Cv % | Total nitrogen flown with water and soil (mg) | Cv % | Total phosphorus flown with water and soil (mg) | Cv % | Total nitrogen flown with water and soil (mg) | Cv % |
| *C. dactylon* | 7.25 ±0.5 | 88.89 | 22.43 ±1.0 | 82.22 | 6.37 ±0.5 | 90.16 | 21.37 ±.5 | 85.62 |
| *S. bengalensis* | 11.28 ±1 | 82.70 | 29.60 ±1.0 | 76.54 | 10.12 ±1.0 | 84.36 | 30.00 ±3.0 | 79.81 |
| *P. hysterophorus* | 38.58 ±3 | 40.83 | 50.73 ±4 | 59.78 | 32.34 ±3 | 50.01 | 47.44 ±3 | 68.07 |
| Bare (control) | 65.20±2 | - | 126.12±3 | - | 64.69±2 | - | 148.57±3 | - |

Values are mean±SD

**Nutrient conservation:** Results are given in Table 2,4. The amount of phosphorus in run-off water and eroded soil were studied on artificial slopes prepared in the garden and on study site.

Movement of different forms of phosphorus on the slopes prepared in the garden showed variations in different vegetated plots. Bare plot showed highest amount of total soluble phosphorus (0.72 mg $l^{-1}$) lost in the surface runoff. The amounts of soluble inorganic and organic phosphorus runoff from bare plot were 0.29 and 0.43 mg $l^{-1}$, respectively. Sediment bound total phosphorus runoff from the bare plot was observed as 23.4 µg $g^{-1}$. Amounts of sediment bound inorganic and organic phosphorus in runoff from the bare plot were 12.8 and 9.6 µg $g^{-1}$, respectively. Plot vegetated with *Cynodon dactylon* showed the lowest amount of water soluble phosphorus (0.58 mg $l^{-1}$) and sediment bound phosphorus (21.1 µg $g^{-1}$) lost in the surface runoff. The amounts of soluble and sediment bound inorganic and organic phosphorus were 0.27 and 0.31 mg $l^{-1}$; 13.1 and 8.0 µg $g^{-1}$, respectively. Plot vegetated with *S. bengalensis* showed the total soluble and sediment bound phosphorus as 0.65 mg $l^{-1}$ and 28.4 µg $g^{-1}$, respectively. The amounts of soluble and sediment bound inorganic and organic phosphorus were 0.29 and 0.36 mg $l^{-1}$; 18.0 and 10.4 µg $g^{-1}$, respectively. Plot vegetated with *P. hysterophorus* showed the total soluble and sediment bound phosphorus as 0.60 mg $l^{-1}$ and 29.6 µg $g^{-1}$, respectively. The amount of total sediment bound phosphorus in plot vegetated with *P. hyseterophorus* was highest among the all vegetated and bare plot. Conservation values of 40.83, 82.70 and 88.89% were observed for *P. hysterophorus*, *S. bengalensis* and *Cynodon dactylon,* respectively.

Plots prepared on the slopes of study site also showed the variations in the amount of phosphorus lost in the surface runoff. Here also the bare plot showed the higher amount of water soluble and soil bound phosphorus (0.76 mg $l^{-1}$ and 21.5 µg $g^{-1}$, respectively) in surface runoff. Plot vegetated with *Cynodon dactylon* on natural slope showed the lowest amount of total water soluble and soil bound phosphorus (0.56 mg $l^{-1}$ and 15.6 µg $g^{-1}$, respectively) in the surface runoff. The amounts of water soluble and sediment bound inorganic phosphorus were 0.25 mg $l^{-1}$ and 10.5 µg $g^{-1}$, respectively. Water soluble and sediment bound organic phosphorus were found to be 0.31 mg $l^{-1}$ and 5.1µg $g^{-1}$, respectively. Total water soluble and sediment bound phosphorus obtained in the plot vegetated with *S. bengalensis* were 0.61 mg $l^{-1}$ and 18.0 µg $g^{-1}$, respectively. The amounts of water soluble and sediment bound inorganic phosphorus were 0.30 mg $l^{-1}$ and 11.5 µg $g^{-1}$, respectively. Organic phosphorus were obtained as 0.31 mg $l^{-1}$ and 7.5 µg $g^{-1}$, respectively in water and sediment runoff. In the plot vegetated with *P. hysterophorus* total soluble and sediment bound phosphorus were 0.67 mg $l^{-1}$ and 20.5 $\mu g\ g^{-1}$, respectively. Inorganic phosphorus, soluble and sediment bound, were obtained as 0.32 mg $l^{-1}$ and 14.5 $\mu g\ g^{-1}$, respectively. Organic phosphorus were obtained as 0.35 mg $l^{-1}$ and 6.5 $\mu g\ g^{-1}$, respectively in water and sediment runoff. Conservation values (CV) are shown in Table 4. *Cynodon dactylon* showed highest CV of 90.16% in conserving phosphorus on the natural slopes. *S. bengalensis* was observed as the second most efficient (84.36% CV) plant species in conserving phosphorus. *P. hysterophorus* showed 50.01% CV and was observed as the least efficient plant species among the three studied plant species.

The mode of phosphorus transport down the slope was largely through water in both vegetated and bare plots and was not much associated with the sediments. Some workers reported that sediment-bound phosphorus trapped by buffers may slowly be leached into the stream, especially once the buffer is saturated (Osborne and Kovacic, 1993; Mander, 1997). In vegetated plot, stabilization of slope soil by existing vegetation led to low phosphorus loss through sediment. Bare plot showed the maximum phosphorus concentration in run-off water which is due to lack of vegetation cover which allowed turbulent interaction between falling rain drops and exposed soil particles.

Minimum concentration of inorganic phosphorus in run-off water was found in the plot vegetated with *Cynodon dactylon*. This was due to adsorption of phosphorus by sediment particles from runoff water (Lowrance, 1998). Bhattacharya and Dutta (2005) showed that phosphorus sorption is affected by soil organic acid. Inorganic phosphorus in runoff water was highest in bare plot. This was due to large quantity of water flowed in runoff and lack of vegetation. Minimum concentration of sediment bound inorganic phosphorus was recorded in the plot of *Cynodon dactylon* because of minimum silt movement, and resorption of phosphorus by vegetative parts (Tomer *et al.*, 2007).

Organic phosphorus in the runoff water was highest in bare plot. Presence of organic debris in the underground plant part left in the plot during the preparation of bare plot added to the amount of organic phosphorus in runoff in addition to other sources. Sediment bound organic phosphorus was found minimum in plot of *Cynodon dactylon* because of low amount of organic debris and protected soil surface which reduced the rain drop energy which results in low silt movement.

It has been stated by many soil scientists that phosphorus does not leach except in very sandy or organic soils because of the chemical interactions between phosphorus and clay minerals. The majority of non-point source phosphorus (George *et al.,* 2008) lost to surface water is generally attached to eroded soil particles. We noticed that the phosphorus movement was determined by erosion and quantity of runoff water. Vegetal cover reduces the energy of rain drops falling on the surface of soil. It reduces the amount of eroded soil which moved down the slope. Speed of water flowed on the slope was highest on the bare plot. The more quantity of water flowed, the more erosion of soil occurred. Dissolved phosphorus percentage was more in the total phosphorus movement down the slope.

Results are given in Table 3,4 for nitrogen conservation. Different forms of estimated nitrogen in soil and water in the surface runoff in different plots prepared in the garden showed variations in their values. Bare plot showed highest amount of total soluble and sediment bound nitrogen (3.45 mg $l^{-1}$ and 4.12 $\mu g\ g^{-1}$, respectively) in its surface runoff. Soluble and sediment bound ammonium and nitrate nitrogen were found to be 3.21 mg $l^{-1}$, 0.14 $\mu g\ g^{-1}$ and 0.24 mg $l^{-1}$, 3.98 $\mu g\ g^{-1}$, respectively. The lowest amount of total soluble and soil bound nitrogen (2.34 mg $l^{-1}$ and 2.48 $\mu g\ g^{-1}$, respectively) was found in the surface runoff from the plot vegetated with *Cynodon dactylon.* Soluble and sediment bound ammonium and nitrate nitrogen were found to be 2.19 mg $l^{-1}$, 0.11 $\mu g\ g^{-1}$ and 0.15 mg $l^{-1}$, 2.33 $\mu g\ g^{-1}$, respectively in the plot vegetated with *Cynodon dactylon*. Total soluble and sediment bound nitrogen obtained in the plot vegetated with *S. bengalensis* were 2.42 mg $l^{-1}$ and 2.67 $\mu g\ g^{-1}$, respectively. Soluble and sediment bound ammonium and nitrate nitrogen were found to be 2.15 mg $l^{-1}$, 0.09 $\mu g\ g^{-1}$ and 0.27 mg $l^{-1}$, 2.58 $\mu g\ g^{-1}$, respectively in the plot vegetated with *S. bengalensis*. In the plot vegetated with *P. hysterophorus,* total soluble and sediment bound nitrogen were found to be 2.51 mg $l^{-1}$ and 3.70 $\mu g\ g^{-1}$, respectively. Soluble and sediment bound ammonium and nitrate nitrogen were found to be 2.21 mg $l^{-1}$, 0.12 $\mu g\ g^{-1}$ and 0.30 mg $l^{-1}$, 3.58 $\mu g\ g^{-1}$, respectively in the plot vegetated with *P. hysterophorus*. Conservation values are shown in Table 4. *C. dactylon* was the most efficient plant species in conserving nitrogen and showed Cv of 82.22%. The second most efficient plant species was observed to be *S. bengalensis* having Cv of 76.54%. *P. hysterophorus* showed the least conservation value (59.78%) amongst the three studied plants.

In the plots prepared on study sites on natural slopes also the nitrogen showed varied amount in the surface runoff. Here, bare plot showed highest amount of total soluble and soil bound (4.16 mg $l^{-1}$ and 5.05 $\mu g\ g^{-1}$, respectively) nitrogen in the surface runoff. Soluble and sediment bound ammonium and nitrate nitrigen were found to be 3.72 mg $l^{-1}$, 0.17 $\mu g\ g^{-1}$ and 0.44 mg $l^{-1}$, 4.88 $\mu g\ g^{-1}$, respectively in the bare plot. Minimum amount of total soluble and soil bound nitrogen (2.35 mg $l^{-1}$ and 2.66 $\mu g\ g^{-1}$, respectively) in the surface runoff was observed in the plot vegetated with *C. dactylon.* Soluble and sediment bound ammonium and nitrate nitrogen were found to be 2.14 mg $l^{-1}$, 0.13 $\mu g\ g^{-1}$ and 0.21 mg $l^{-1}$, 2.52 $\mu g\ g^{-1}$, respectively. Total soluble and sediment bound nitrogen obtained in the plot vegetated with *S. bengalensis* were 2.37 mg $l^{-1}$ and 2.71 $\mu g\ g^{-1}$, respectively. Soluble and sediment bound ammonium and nitrate nitrogen were found to be 2.13 mg $l^{-1}$, 0.10 $\mu g\ g^{-1}$ and 0.24 mg $l^{-1}$, 2.61 $\mu g\ g^{-1}$, respectively in the plot vegetated with *S. bengalensis*. In the plot vegetated with *P. hysterophorus* total soluble and sediment bound nitrogen were found to be 2.52 mg $l^{-1}$ and 3.81 $\mu g\ g^{-1}$, respectively. Soluble and sediment bound ammonium and nitrate nitrogen were found to be 2.18 mg $l^{-1}$, 0.15 $\mu g\ g^{-1}$ and 0.34 mg $l^{-1}$, 3.66 $\mu g\ g^{-1}$, respectively in the plot vegetated with *P. hysterophorus*. Conservation values for nitrogen were observed 85.62, 79.81 and 68.07%, respectively for *C. dactylon, S. bengalensis* and *P. hysterophorus.*

Movement of nitrogen was observed under ammonium nitrogen and nitrate nitrogen. As nutrients are always lost through runoff water and eroded soil, the amount of runoff water and eroded soil directly affect the nutrient loss. The variation in the loss of nutrient also depends upon the varied ground cover provided by different vegetated species (Raju *et al.*, 1997). *C. dactylon* showed highest conservation values for nitrogen because amount of runoff water and eroded soil was minimum in this plot. *C. dactylon* form a thick vegetative cover on the ground which reduces splash erosion of soil. Vegetative parts also form micro topographic depression which reduces the free flow of surface water. Nitrogen primarily leaches from the abscised parts of the plant and that is why total nitrogen loss was observed maximum in bare plot because of the presence of underground plant parts which were left during the making of plot bare. Also the large amount of runoff water and eroded soil were the reasons of excess nitrogen loss on the bare plot.

Soluble ammonium nitrogen was found in minimum concentration in the plot vegetated with *C. dactylon,* whereas the maximum concentration of ammonium nitrogen was found in the plot vegetated with *P. hysterophorus*. This is because the movement of ammonium down the slope was largely through water. High concentration of ammonium nitrogen in runoff water was largely due to greater leaching from partially decomposed remains and its easy solubility. Loss of ammonium through water is affected by amount of litter in the plot whereas the loss in particulate form is due to canopy cover and soil moisture content (Mitsch and Gosselink, 1993).

Nitrate nitrogen is closely related to the metabolism of plants, which, in turn, depends on the growth stage of the vegetation concern. Nitrate nitrogen is most feebly adsorbed to colloides. This adsorption makes it highly mobile in soil as well as in the biological system, hence the high leaching rate. Different vegetation cover affect the leaching rate (Groffman *et al.,* 1992; Srivastava, 2007) that's why in different plots variation in the conc. of nitrate nitrogen in runoff water and eroded soil was observed. The mode of nitrate nitrogen transport was largely through soil because of non polar nature of nitrogen, rendering it insoluble in water.

It was observed that *Cynodon dactylon* was the most efficient riparian species in conservation of soil, water and nutrients in surface runoff.

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## References


Ambasht, R.S. and N.K. Ambasht: Conversation of soil and nutrients through plant cover wetland margins. Edited Book: Modern trends in applied terrestrial ecology, Springer New York. pp. 269-280 (2003).

Ambasht, R.S.: Conservation of soil through plant cover of certain alluvial slopes in India. Proc. IUCN XI Tech. Meeting, Morges, Switzerland. pp. 44-48 (1970).

APHA: Water Environment Federation and American Water Works Association, Standard methods for the examination of water and wastewater 20th Edn., American Public Health Association Washington, USA (1998).

Azous, A.L. and R.R. Horner (Eds:) Wetlands and urbanization: Implications for the future. Lewis Publishing, Boca Raton FL (2000).

Bhattarchrya, Pratap and S.C. Datta: Effect of organic acids and silicate on phosphorus concentration, buffering capacity and release threshold level in soil. *J. Ind. Soc. Soil Sci.,* **53**, 577-583 (2005).

Bishop K., J. Seibert, S. Kohler and H. Laudon: Resolving the double paradox of rapidly mobilized old water with highly variable responses in runoff chemistry, *Hydrological Processes,* **18**, 185-189 (2004).

Daniels, R. B. and J. W. Gilliam: Sediment and chemical load reduction by grass and riparian filters. *Soil Sci. Soc. Am. J.*, **60**, 246-251 (1996).

Fennessy, M.S. and J.K. Cronk: The effectiveness and restoration potential of riparian ecotones for the management of nonpoint source pollution, particularly nitrate. *Criti. Rev. Environ. Scie. Technol.,* **27**, 285-317 (1997).

George, N., R. Zaimes, C. Schultz, M. Thomas and M. Isenhart: Total phosphorus concentrations and compaction in riparian areas under different riparian land-uses of Lowa. *Agri. Ecosys. Environ.*, **127**, 22-30 (2008).

Groffman, Peter M., Arthur J. Gold and Robert C. Simmons: Nitrate dynamics in riparian forests: Microbial studies. *J. Environ. Qual.*, **21**, 666-671 (1992).

Hansen, J.C., B.J. Cade-Menun and D.G. Strawn: Phosphorus speciation in manure amended alkaline soils. *J. Environ. Qual.*, **33**, 1521-1527 (2004).

Jackson, M.L.: Soil Chemical Analysis. Prentice-Hall, New Delhi. p. 498 (1967).

Lowrance, R.R.: Riparian forest ecosystems as filters for nonpoint-source pollution. *In*: Successes, Limitations and Frontiers in Ecosystem Science (*Eds*.: M.L. Pace and P.M. Groffman). Springer Verlag. Management. Waltham, MA: USACE. pp. 113-141 (1998).

Mander, V.K., K. Lohmus and T. Mauring: Efficiency and dimensioning of riparian buffer zones in agricultural catchments. *Ecol. Eng.*, **8**, 299-324 (1997).

May, C.W., R.R. Horner, J.R. Karr, B.W. May and E.B. Welch: Effects of urbanization on small streams in the puget sound lowland ecoregion. *Watershed Protection Techniques*, **2**, 483-494 (1997).

Michael, G. D., P. Vidon, N. P. Gurwick, C. J. Allan, T. P. Duval and R. Lowrance: The role of riparian vegetation in protecting and improving chemical water quality in streams. *J. American Water Resour. Assoc.,* **46**, 261-277, (2010).

Misra, R.: Ecology Work Book. Oxford and IBH Publishing Company, New Delhi (1968).

Mitsch, W.J. and J.G. Gosselink: Wetlands, 2nd Edn. Van Nostrand Reinhold, New York (1993).

Naiman, R.J., R.E. Bilby, D.E. Schindler and J.M. Helfield: Pacific Salmon, nutrients and the dynamics of freshwater and riparian ecosystems. *Ecosystems,* **5**, 399-417 (2002).

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean: Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. of Agric. Circ. 939 (1954).

Ortega Klett, C.T.: New Mexico Water Rights. 2nd Update. New Mexico Water Resources Research Institute. New Mexico State. Las Cruces, NM (2002).

Osborne, L.L. and D.A. Kovacic: Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biol.*, **29**, 243-258 (1993).

Peach, K. and M.V. Tracey: Modern methods of plant analysis, Springer-Verlag (1956).

Raju Kumar, R.S. Ambasht and N.K. Srivastava: Nitrogen conservation efficiency of five common riparian weeds in a runoff experiment on slopes. *J. Environ. Manag.,* **34**, 47-57 (1992).

Raju Kumar, R.S. Ambasht, Ajit K. Srivastava and N.K. Srivastava: Role of some riparian wetland plants in reducing erosion of organic carbon and selected cations. *Ecol. Eng.*, **6**, 227-239 (1996).

Raju Kumar, R.S. Ambasht, Ajit K. Srivastava, N.K. Srivastava and A. Sinha: Reduction of nitrogen losses through erosion by *Leonotis nepetaefolia* and *Sida acuta* in simulated rain intensities. *Ecol. Eng.*, **6**, 233-239 (1997).

Shafroth, P.B., J.C. Stromberg and D.T. Patten. Riparian vegetation response to altered disturbance and stress regimes. *Ecol. Appli.,* **12**, 107-123 (2002).

Srivastava, N.K., C. Ram Lal and R.E. Masto: Role of selected riparian herbs in reducing soil erosion and nutrient loss under simulated rainfall. *Environ. Earth Sci*. **61**, 405-417 (2010).

Srivastava, Prabodh.: Nitrogen conservation efficiency of weeds in runoff experiments on artificial and natural slopes. *Ind. J. Appl. Pure Biol.,* **22**, 185-190 (2007).

Subbiah, B.V. and G.L. Asija: A rapid procedure for the determination of available nitrogen in soils. *Curr. Sci.,* **25**, 259-260 (1956).

Tomer, M.D., T.B. Moorman, J.L. Kovar, D.E. James and M.R. Burkart: Spatial patterns of sediment and phosphorus in a riparian buffer in western Lowa. *J. Soil Water Conser.,* **62**, 329-338 (2007).

Turner, B.L, N. Mahieu and L.M. Condron: Phosphorus-31 nuclear magnetic resonance spectral assignments of phosphorus compounds in soil NaOH EDTA extracts. *Soil Sci. Soc. Am. J.,* **67**, 497-510 (2003a).

Turner, B.L, N. Mahieu and L.M. Condron: The phosphorus composition of temperate pasture soils determined by NaOH EDTA extraction and solution 31P NMR spectroscopy. *Organic Geochem.*, **34**, 1199-1210 (2003b).

U.S. Army Corps of Engineers (USACE): Buffer strips for riparian zone (1991).

United States Department of Agriculture Natural Resource Conservation Service (USDA-NRCS). Riparian area and recognition, part 411. In Ecological SitesTitle110.GeneralManual.http://policy.nrcs.usda.gov/scripts/lpsiis.dll/GM/GM_190_411.htm (2005).