Journal of Environmental Management (1984) **18,** 99–104

Soil, Water and Nutrient Conservation by Certain Riparian Herbs

R. S. Ambasht, M. P. Singh and Eklabya Sharma

Centre of Advanced Study in Botany, Banaras Hindu University, Varanasi-221005, India

Received 15 *February* 1983

In order to assess experimentally the quantitative roles in binding the soil, nutrient conservation and retarding water runoff and soil erosion, six herbaceous species dominant on the banks of the River Gomti at Jaunpur (India) were selected. Young seedlings collected from the river bank were sown on sloping experimental plots in the Botanic Garden, Banaras Hindu University. Known quantities of water were sprayed on vegetated and bare plots, and runoff water and soil were collected in separate cemented reservoirs. Using a technique described by Ambasht (1970), the soil conservation value of selected grasses and sedge was found to range from 87·6 to 95·4%, and of dicotyledon weeds from 52·8 to 93·8%. The plants retarded water runoff by about 60%, compared with the bare plot. Ambasht's formula for soil conservation value has been modified to establish water conservation values for herbaceous cover, compared with the bare plot, and these values ranged from 65 to 74% for grasses and sedge, and 27 to 72% for dicotyledon weeds. The physico-chemical properties of the soil of the bare plot, vegetated plots and eroded soils were compared to determine the role of these herbaceous species in maintaining soil quality and fertility.

Keywords: conservation value, infiltration, nutrient, riparian, soil erosion, water runoff.

1. Introduction

Riparian ecosystems undergo frequent erosion, flooding and silting. Normally, permanent vegetation cover in the form of afforestation is ideal to stabilize the system, and also to check erosion and river meandering. However, in the Indian plains, the dense human population leaves little scope for anything on the fertile lands other than habitation and crop production. Jaunpur district is one such place, traversed by the River Gomti—a tributary of the famous River Ganga into which it flows a few miles further east. Its banks, on either side, are mostly cultivated for winter season crops like wheat, barley and chick pea, but, in summer and rainy seasons, they are mostly left fallow either

0301-4797/84/02099+06 $03.00/0

because of dryness or excessive floods. There are certain regions where crop cultivation is negligible because of the precipitous embankments. On Indian riparian ecosystems, Ambasht (1970) has advocated the conservation of soil against rain and runoff forces by planting strips of perennial grasses between the agricultural fields at regular intervals, to provide effective checks and impede soil movement without affecting the crops. He has devised a technique for evaluating the effectiveness of herbs in checking soil erosion.

The ancient city of Jaunpur has begun to experience frequent floods in recent years. One possible reason might be the gradual raising up of river beds with soil inflow from banks, caused by frequent and large-scale erosion.

There has been increasing biotic pressure from grazing, scraping, bathing, cloth washing with alkali earth (reh), etc., all of which help to eliminate the native herbaceous vegetation. How much the different dominant grasses, sedges and dicotyledon weeds contribute in binding the soil, increasing water infiltration, improving the physical and chemical properties of soil, etc., are aspects of direct applied interest to conservation ecologists. We have tried to find the answers to such questions in this research project.

2. Materials and method

On the river of the Gomti, two sites were selected on the same side, of almost equal slope. The first site was neglected and was covered with natural weed species throughout the year. The second site was covered with weed species in summer and in the rainy seasons, and with winter crops for a period of 4 months. Each site was divided into three zones—upper, middle and lower—according to river water level. Five dominant species and one species of frequent occurrence have been selected for the culture studies to determine soil conservation and water conservation values. The selected dominant, rainy season species were *Cynodon dactylon* (L.) Pers., *Phyla nodiflora* (L.) Greene, *Cyperus rotundus* L., *Croton bonplandianum* Bail, *Crotalaria medicaginea* Lamk., and the most frequently occurring species was *Digitaria adscendens* (H.B. & K.) Hemr.

Propagules of the above species were collected from the river bank and transplanted on plots sloping at an angle of 13° in the Botanic Garden, Banaras Hindu University. Seven plots were prepared (each 1×3 m), three plots in an east–west direction facing north, and four plots in an east–west direction facing south. Six plots were vegetated, each with a separate species, leaving the seventh plot completely bare. On each of the sloping experimental plots, different species were planted at uniform density, but, because of vegetative propagation, aerial cover increased differently with different species throughout the study period. At the base of the slopes, cemented tanks were prepared to catch the water runoff and eroded soil from each plot. The foliage growth was sufficient to cover the ground completely after about 8–10 weeks. The negligible occurrence of other plant species was left, except for careful weeding at an early stage so as not to disturb the soil of the plots. Artificial spraying was applied for 30 min using a multipore nozzle with 2 mm diameter perforations from 1 m height at a constant speed of 16 l/min. The showering was done at 15-day intervals for three consecutive fortnights. The quantities of water sprayed, water runoff and the soil eroded and deposited in the reservoirs from each of the vegetated plots and the bare plot were obtained. Water sampling was done immediately to avoid any loss through evaporation, and soil samples were collected and oven dried at 105°C for 36 hr. The soil sample dry weight was taken and used for physical and chemical analysis (Jackson, 1958). The soil conservation value (CV) of each of the six species was calculated, using the formula given by Ambasht (1970):

because of dryness or excessive floods. There are certain regions where crop cultivation is negligible because of the precipitous embankments. On Indian riparian ecosystems, Ambasht (1970) has advocated the conservation of soil against rain and runoff forces by planting strips of perennial grasses between the agricultural fields at regular intervals, to provide effective checks and impede soil movement without affecting the crops. He has devised a technique for evaluating the effectiveness of herbs in checking soil erosion.

The ancient city of Jaunpur has begun to experience frequent floods in recent years. One possible reason might be the gradual raising up of river beds with soil inflow from banks, caused by frequent and large-scale erosion.

There has been increasing biotic pressure from grazing, scraping, bathing, cloth washing with alkali earth (reh), etc., all of which help to eliminate the native herbaceous vegetation. How much the different dominant grasses, sedges and dicotyledon weeds contribute in binding the soil, increasing water infiltration, improving the physical and chemical properties of soil, etc., are aspects of direct applied interest to conservation ecologists. We have tried to find the answers to such questions in this research project.

2. Materials and method

On the river of the Gomti, two sites were selected on the same side, of almost equal slope. The first site was neglected and was covered with natural weed species throughout the year. The second site was covered with weed species in summer and in the rainy seasons, and with winter crops for a period of 4 months. Each site was divided into three zones—upper, middle and lower—according to river water level. Five dominant species and one species of frequent occurrence have been selected for the culture studies to determine soil conservation and water conservation values. The selected dominant, rainy season species were *Cynodon dactylon* (L.) Pers., *Phyla nodiflora* (L.) Greene, *Cyperus rotundus* L., *Croton bonplandianum* Bail, *Crotalaria medicaginea* Lamk., and the most frequently occurring species was *Digitaria adscendens* (H.B. & K.) Hemr.

Propagules of the above species were collected from the river bank and transplanted on plots sloping at an angle of 13° in the Botanic Garden, Banaras Hindu University. Seven plots were prepared (each 1×3 m), three plots in an east–west direction facing north, and four plots in an east–west direction facing south. Six plots were vegetated, each with a separate species, leaving the seventh plot completely bare. On each of the sloping experimental plots, different species were planted at uniform density, but, because of vegetative propagation, aerial cover increased differently with different species throughout the study period. At the base of the slopes, cemented tanks were prepared to catch the water runoff and eroded soil from each plot. The foliage growth was sufficient to cover the ground completely after about 8–10 weeks. The negligible occurrence of other plant species was left, except for careful weeding at an early stage so as not to disturb the soil of the plots. Artificial spraying was applied for 30 min using a multipore nozzle with 2 mm diameter perforations from 1 m height at a constant speed of 16 l/min. The showering was done at 15-day intervals for three consecutive fortnights. The quantities of water sprayed, water runoff and the soil eroded and deposited in the reservoirs from each of the vegetated plots and the bare plot were obtained. Water sampling was done immediately to avoid any loss through evaporation, and soil samples were collected and oven dried at 105°C for 36 hr. The soil sample dry weight was taken and used for physical and chemical analysis (Jackson, 1958). The soil conservation value (CV) of each of the six species was calculated, using the formula given by Ambasht (1970):

$$CV = 100 - \left(\frac{S_{wp}}{S_{wo}} \times 100\right)$$

where S_{wp} is the weight of soil washed from vegetated plots and S_{wo} is the weight of soil washed from the bare plot under identical erosional stresses.

The above formula for soil conservation value has been used here for the first time to determine the water conservation value of herbaceous plants. The S_{wp} and S_{wo} are replaced by W_{wp} and W_{wo} to denote, respectively, weights of water lost from planted and open (bare) plots, in this case CV refers to water conservation instead of soil conservation.

Mean values obtained from the three shower applications were used in the above evaluation.

3. Results

On the bare plot, 7·8 kg of the soil loss was obtained after 30 min of showering, which was the maximum value of eroded soil. The bare plot had the least infiltration (18%) of water and the maximum runoff (82%). The quantities of soil eroded from the vegetated plots were 0·36 kg (*C. dactylon*), 0·48 kg (*P. nodiflora*), 0·69 kg (*C. rotundus*), 0·97 kg (*D. adscendens*), 2·50 kg (*C. bonplandianum*) and 3·68 kg (*C. medicaginea*). The vegetated plots had higher infiltration rates and less runoff than the bare plot (Table 1). *Cynodon dactylon* had the highest water conservation value of 74%; *P. nodiflora* was the next most effective species having 73% water conservation value; and *C. rotundus*, *D. adscendens*, *C. bonplandianum* and *C. medicaginea* show progressively lower values (Table 1). The runoff soil deposited in the reservoirs contained greater proportions of the finer particles like clay and silt, and less of sand, compared with the samples from the plots before showering. An equal proportion of silt, clay and sand was found in the eroded soils from vegetated plots, in contrast to soil samples from the bare plot with a higher content of silt (45%) and clay (43%) but less sand (10%) (Table 2).

The physico-chemical properties of the soil of the bare plot had 1·7% organic matter,

TABLE 1. Water and soil runoff quantities and conservation values

Plot	Water runoff (kg)	Water runoff (%)	CV for water (%)	Soil loss (kg)	CV for soil (%)
Plot 1 *Cynodon dactylon*	101	21·04	74·23	0·36	95·4
Plot 2 *Phyla nodiflora*	106	22·08	72·95	0·48	93·8
Plot 3 *Cyperus rotundus*	114	23·75	70·91	0·69	91·1
Plot 4 *Digitaria adscendens*	136·5	28·44	65·17	0·97	87·6
Plot 5 *Croton bonplandianum*	205	42·71	47·70	2·50	68·0
Plot 6 *Crotalaria medicaginea*	285	59·38	27·29	3·68	52·8
Plot 7 Bare	392	81·67	—	7·80	—

CV = Conservation value.

1·0% organic carbon, 0·052% total nitrogen, with 19 C/N ratio, a porosity of 29% and a water-holding capacity of 31% (Table 3). The values were highest under the *C. dactylon*-covered plot compared with the other five plots in all respects: organic matter (3·1%), organic carbon (1·3%), total nitrogen (0·086%), porosity (43·5%) and water-holding capacity (36%).

4. Discussion

When comparing the parent stock from which the slopes were prepared with the present conditions of the different plots, it has been observed that the vegetation conserved and developed soil properties and qualities advantageous for plant growth. The plant cover protects the soil quite effectively from the heavy impact of rain drops in the frequent artificial showering. The above-named plant plots have favourable levels of nitrogen, organic carbon, porosity and water-holding capacity, and least surface runoff.

Frequent showering on the bare plot caused a lot of soil deposition in the tanks, with consequent impoverishment of soils on the slopes, whereas the soil condition was

TABLE 2. Mechanical composition of soils in different stages of the experiment

		Clay (%)	Silt (%)	Sand (%)
Parent stock		20·90	26·15	53·68
Plot 1	BS	19·93	25·20	54·21
Cynodon dactylon	AS	19·10	24·63	55·86
	L/G	−0·83	−0·57	+1·65
	DS	29·45	34·14	34·72
Plot 2	BS	19·60	25·00	54·10
Phyla nodiflora	AS	18·86	24·32	56·21
	L/G	−0·74	−0·68	+2·11
	DS	30·41	34·36	33·53
Plot 3	BS	18·92	24·86	54·97
Cyperus rotundus	AS	18·34	24·11	56·00
	L/G	−0·58	−0·75	+1·21
	DS	30·93	35·10	32·80
Plot 4	BS	18·36	24·65	55·32
Digitaria adscendens	AS	17·89	23·92	56·81
	L/G	−0·47	−0·73	+1·49
	DS	31·41	35·66	31·72
Plot 5	BS	17·45	24·16	55·23
Croton bonplandianum	AS	17·10	23·68	58·20
	L/G	−0·35	−0·48	+2·97
	DS	32·16	36·24	30·83
Plot 6	BS	15·62	24·23	58·83
Crotalaria medicaginea	AS	15·18	23·63	60·10
	L/G	−0·44	−0·60	+1·27
	DS	36·42	38·13	24·25
Plot 7	BS	13·67	22·49	62·89
Bare	AS	11·40	19·63	68·30
	L/G	−2·27	−2·86	+5·51
	DS	43·10	45·32	10·54

BS = Before showering; AS = after showering; L/G = loss or gain; DS = deposited soil.

TABLE 3. Physical and chemical properties of soils at different stages of the experiment

	Porosity (%)	Water-holding capacity (%)	Organic carbon (%)	Organic matter (%)	Total nitrogen (%)	C/N ratio
Parent stock	38·29	32·65	1·26	2·17	0·063	20·00
Before showering						
Plot 1	43·50	36·37	1·82	3·13	0·086	21·16
Plot 2	41·36	35·82	1·73	2·98	0·081	21·36
Plot 3	40·82	35·63	1·68	2·89	0·079	21·27
Plot 4	38·14	35·21	1·62	2·79	0·077	21·04
Plot 5	36·61	34·18	1·45	2·49	0·073	19·86
Plot 6	34·35	33·21	1·38	2·37	0·069	20·00
Plot 7	28·60	31·28	1·01	1·74	0·052	19·42
Deposited soil						
Plot 1	—	—	0·69	1·19	0·033	20·91
Plot 2	—	—	0·68	1·17	0·034	20·00
Plot 3	—	—	0·78	1·34	0·034	22·94
Plot 4	—	—	0·82	1·41	0·036	22·78
Plot 5	—	—	0·65	1·12	0·037	18·38
Plot 6	—	—	0·67	1·15	0·039	17·18
Plot 7	—	—	0·51	0·88	0·031	16·45

maintained and improved under the cover of six plant species. *Crotalaria medicaginea* had the least conserving value; its root system grows downwards with very little lateral root mesh on the upper region (Ambasht, 1962). Splashing of the rain drops on the bare area caused the finer particles to come to the surface with the beating effect, thus clogging and sealing the surface layer and reducing the infiltration rate. This effect was checked in the vegetated plots, but to different degrees depending upon the plant species. The coverage of *C. dactylon* and *P. nodiflora* was maximal, with trailing parts rooting at each node. *Digitaria adscendens*, which is not so dominant a species, also had a high conservation value, because of its luxuriant aerial growth which reduced the beating effect of the rain drops. In the bare plot, the frequent showers resulted in the loss of finer particles and nutrient depletion, thus leaving a sandy texture.

Cynodon dactylon, *P. nodiflora*, *C. rotundus* and *D. adscendens* had high soil conservation values of 95·4%, 93·8%, 91·1% and 87·6% respectively, as they form a thick cushion, allowing greater infiltration. Organic carbon and nitrogen content are conserved, in addition to improved soil porosity and water-holding capacity. The other two species, *C. bonplandianum* and *C. medicaginea*, have fairly good soil conservation values of 68·0% and 52·8% respectively. Comparing the water conservation value of the vegetated plots with the bare plot clearly shows the plant species' importance in conserving this resource for its better utilization, and, at the same time, preventing floods to some extent under extensive vegetative cover. The annual and perennial herbs and shrubs in flood-prone river banks play an indispensable role.

If the above six species are allowed to grow in the neglected area of the river banks, and are protected from biotic stresses such as grazing, scraping, and the removal of *C.*

medicaginea and *C. bonplandianum* stems for fuel, the sloping river bank will have a reduced erosional rate. Reduced soil loss and greater water infiltration brought about by the vegetation cover will serve a multiple purpose (a) protecting the habitat, (b) checking river meandering, (c) reducing silt deposition on the river bed, (d) reducing the input of clean rather than muddy water, (e) improving the water-carrying capacity of river, and reducing the frequency of overflooding of surrounding uplands, (f) improving fertility status and nutrient conservation, (g) improving soil texture with less sandy top soil and (h) reducing dust bowls in summer, etc.

Grateful thanks are due to the University Grants Commission and the Council of Scientific and Industrial Research for awarding research fellowships to two authors (MPS and ES respectively).

References

Ambasht, R. S. (1962). Root habitats in response to soil erosion, silting and inundation. Ph.D. Thesis, Banaras Hindu University.

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

Jackson, M. L. (1958). *Soil Chemical Analysis.* Englewood Cliffs, New Jersey: Prentice-Hall.