WATER, SOIL AND NUTRIENT CONSERVATION IN RIPARIAN ECOSYSTEM

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Rivers are natural bodies of flowing (lotic) water of comparatively recent geological times formed as a result of physical process of conversion of rainfall and melting snow into streamflow. Several such streams, as they flow down the gradient converge and merge into bigger streams. Rivers perform the principal function of balancing the annual hydrological cycle between the land sea exchanges. The land and sea contribute 16 and 84% respectively to global evaporation of water into the atmosphere, while the respective global distribution of rain water is 23 and 77% on land and sea surfaces.

Zonations and Zonal Qualities: In the longitudinal axis, the rivers originating in hilly region, flow down at varying fast speeds i.e. in ‘torrents’, often forming big cascades and waterfalls as they run roaring down the rocks. The rivers then on reaching gentler slopes slow down to ‘swift zone’ type and on reaching the plains the speed of current further slows and the river becomes ‘less swift’ and then ‘slow’ in which state they cover long distances before approaching to sea mouth when the gradient becomes negligible and the rivers split into several rivulets in a ‘sluggish’ phase and form extensive deltas. All along its course the river water quality gets influenced and modified by the geology and nature of soil through which it passes and by the quality of effluents and water of tributaries joining it.

The rivers while performing the return of surplus water to sea provide ready stock of water which mankind takes out for a very large number of uses. Dams are constructed in the hilly terrains and barrages elsewhere to store and divert water for hydroelectric generation, irrigation through canals, rearing fishes, water supply to industries, municipal needs, etc. River banks have been the sites of human settlements and nucleus of rural and urban growth due to easy and perennial supply of drinking water, domestic water needs including for live stocks, bathing, washing of clothes, swimming and aquatic sports. On flood plains and exposed riparian lands there is hardly any need of external input of irrigation water or fertilizer for an easy raising of good crops yields. On the uplands, through lift pumps water is obtained for irrigation over big command areas. Additional advantages to village and town dwellers on river banks are for easy water-way transports by boats for men, and merchandise between cities, trade centres and sea ports.

In the lateral axis, river corridor has three main components, first the central perennial water course, second the sloping embankments which in the rainy season become the part of flowing water zone and the third are flood plains which get water covered occasionally. The embankment slopes and immediately adjacent uplands are ecotonal in nature and rich in plant diversity. These under natural conditions serve as the buffer between the upland and the main water course. These act as sinks and filters of pollutants from domestic, municipal and industrial sources and runoff material from the agricultural fields fertilizers and pesticides. This is an extremely important function required to prevent the pollution of river water necessary for human health. In the event of destruction of vegetation on riparian slopes not only the river gets more and more polluted but erosion, siltation, soil impoverishment, creation of ravines and gullies also take place. Nutrient enriched water begins to show eutrophication, a phenomenon associated with (i) explosive growth of aquatic vegetation; (ii) accumulation of dead debris, (iii) increased population of decomposer microbes consuming dissolved oxygen and creating anoxia leading to (iv) fish mortality, (vi) increasing BOD and (vii) turning the once clean potable water
into dirty, foul smelling water full of microbes including disease causing pathogens. Toxic chemicals reaching the water body through food chain reach to man in a highly biologically magnified proportion, may be thousands of times more concentration than their original concentration in the receiving water.

River, like the soil is a living ecosystem full of life. The different trophic level organisms through food chain and in other ways are interlinked and interdependent. Aquatic ecosystems in a balanced state have the built in regulatory mechanism of self purification operative within a certain limit, beyond which either eutrophication sets in or the water becomes too toxic for living organisms.

River Corridor Stresses and Anthropogenic Pressures: We take up the example of River Ganga in this paper to illustrate different aspects of river corridor ecology and the role of plants in the conservation of soil, water and nutrients. River Ganga and its tributaries in the Gangetic plains of North India sustain about 200 million people of which about 160 million live in the rural environs and the rest in cities. This is among the densest pocket of human population on the earth, as such the severity of anthropogenic pressures including pollution is of a very high order.

The pulses and fluxes operating on the river corridors are flooding pulse which occur normally once in a year during rainy season. Goodrich (1974) and Wistendahl (1958) have shown that site to site variations have marked difference on the effect of flood on vegetation and the habitats. Only flood tolerant species survive due to physiological adaptations. Floods usually enrich the soil fertility near the coastal region. Hurricane pulse is a strong force that determines the stability of vegetation. Another flux is of continuous arrival of plant propagules from distant lands carried through water current and getting deposited on the river embankments and grow there. Alhagi and Tamarix arrive in this way at Varanasi, grow only on the river banks as they have failed to enter the upland plains. (Ambasht, 1968). Major cities with extensive discharge of industrial effluents and sewage disposals on Ganga bank are Hardwar (antibiotic industry), Ailgarh (power house, brass and steel industry) Kanpur (cotton and woolen mills, leather tanneries and plastics), Allahabad (confluence with River Yamuna bringing pollutants from Delhi, Mathura and Agra), Mirzapur (metal works and woven carpets), Varanasi (paper, chemicals, fertilizer, locomotive engines, silk and woolen cottage industries, metal works), Ghazipur (river Gomati bringing polluted waters of Lucknow and Jaunpur, opium factory), Patna (confluence with river Sone which brings effluents from industrial towns of Sonebhadra and Dalmaranagar), Barauni and Mokamah (oil refinery shoe factory, thermal power, fertilizer factory and distillery), Bhabalpur, (silk clothes), Howrah and Calcutta (densest congregation of human population with thousands of small and big industries).

All along the river corridor, despite a high density of human population, there has been a tremendous amount of biodiversity of economically important plants and animals. Man has been using the nonconsumptive abioc resources including transports for man and material by boats and logs by floatation, hydroelectric power generation, bathing and recreation, and consumptive use of taking water for drinking, domestic, irrigation and industrial uses and collection of huge amount of sand for building constructions. Biotic resources commonly taken out from the river corridors are: wood for fuel supply and construction of household articles, carts and agricultural appliances; live stock maintenance, fisheries, game birds and other wild animals. Many medicinal plants, tall hardy grasses used for thatching huts and house roofs, the all important jute plants and many cereals and pulses are raised on the Ganga river corridors. besides these consumptive and nonconsumptive direct uses, the indirect uses of river corridor soil and provide stability and water quality to the river ecosystem and of course all other attributes of a green cover. But in recent decades the rise in human population and developmental activities with utter disregard to ecological principles have started degrading the river corridors very badly.

The main anthropogenic pressures are overuse of certain spots of the river banks for recreation and for mass bathing at special functions. This causes mechanical injuries to ground floor vegetation including the tree seedlings. Grazing by cattle, goat and sheep are ever increasing and causing a decline in the vegetal cover. Trampling also losens the
surface soil which is rather sandy. This leads to
accelerated erosion and instream sediment load
(Duff, 1979). While light grazing produces improve­
m ent in the river corridor (May and Davis 1982, 
Platts 1982), heavy grazing on the other hand is a
injurious. Controlled deferred grazing and appro­
 priate ratio of herbs, shrubs and trees could bring
better stability.

Owen (1971) has given that the main pollutants
are: (i) sewage (ii) infectious agents (iii) nutrients, 
(iv) synthetic organic chemicals (v) inorganic chemi­
cals (vi) sediment (vii) radioactive material and 
(viii) heat. There are numerous episodes of heavy
human mortality on account of drinking polluted
waters in the Gangetic Plains. Pollution of River
Ganga is quite acute. At Varanasi, there are about
3000 very small to medium industries dealing with
food processing, weaving of fabrics and carpets,
dyeing of cotton and silk clothes and wooden car­
pets, wooden toys, chemicals and fertilizers, metal
works printing and a large number of electrical
goods including fans, motors and motor pumps.
There is a big industry of Diesel Locomotive Engines
and medium size industries of paper, glass, plastics
and many kinds of food processing and cigarettes.
Further about 25 million gallons of sewerage are
discharged per day which may have a high BOD of
about 500 mg l⁻¹. More than 30,000 dead human
bodies are cremated using about 10,000 tons of
wood every year on Harischandra and Manikarnika
cremation ghats in the Southern and Northern part
of the city respectively. This releases considerable
quantities of ash of burnt wood and dead bodies and
may increase the water temperature to cause ther­
mal blocks to migratory fishes, reduce DO and
unaesthetic sites of vultures and dogs clamouring
over the floating and unburnt portions of dead bodies.
Another important source of pollution is the bulk
washing of clothes by washermen using alkali earth
(Reh) and sometimes soaps and detergents. These
add to change in pH, enrichment of phosphates and
eutrophication. On bathing festivals, hundreds of
thousands of pilgrims take bath in some major citi­
ies. The Ganga Project Directorate has taken up the
challenge of reducing river pollution by putting the
municipal and factory discharges to suitable pre­
treatment and have constructed sewar treatment tanks.
Heavy metal toxicity is getting severe at certain
places while nitrogen enrichment particularly of the
ground water is likely to be the most serious human
health problem in near future.

Erosion, Runoff and Conservation: The forma­
tion of soil takes place very slowly and a mature
profile from parent rock to a reasonably thick top
soil may require 50 to 100 years, but on the river
banks water transported alluvium gets repeatedly
covered by siltation or exposed by erosion leaving
very little time for the development of a natural
profile. Natural soil erosion is a very slow process.
On river corridors erosional process is intense and
when there is a vegetation destruction in the watersheds and river banks, the soil erosion becomes
acute. Lazarus (1990) mentions that, “world wide,
25,000 millions tons of soil are being washed away
each year and the process is not confined to the
developing world only. The United States have lost
about one third of its top soil since the farming
began”. River corridors are normally the conver­
gence point of the eroded material and the river
water gets charged with silt load. In India, the problem
of soil erosion is very acute.

Stocking (1984) has emphasized the importance
of vegetation in abatement of soil erosion and sta­
bilization of river corridor ecosystems. Vegetation
intercepts the raindrops and dissipates the kinetic
energy so that the soil is protected against the rain
beating effect. There is a continuous struggle be­
 tween the vegetation cover and erosion. Human
interference and grazing disturb the balance in favour
of erosion. Thornes (1989) gives a model on veg­
etation and erosion struggle and this helps in evalu­
at ing the critical stage when a “push” would shift
the system to either a good vegetal cover side or
into a denudation side. Anwar et al. (1989) have
found that shrubs were more effective in halting
runoff and erosion. Frankenberg (1989) reported
that Phragmites australis on the river corridors of
river Murray in Australia is a very good to check
erosion.

Ambasht (1962, 1970) gave the term ‘conser­
vation value’ which refers to the percentage of soil,
water or nutrients not allowed to erode i.e. con­
served by the vegetal cover of a species or com­
 munity growing on an area and subjected to rainfall
or water showering as compared to the erosional or
run off losses from an equal sized adjacent area
cleared of all vegetal cover (bare) and subjected to
same rainfall or showering treatment. From the weight values of losses from vegetated (sp.) and bare (So) plots the conservation value (Cv%) is calculated by the formula: \( \text{Cv} = 100 \left( 1 - \frac{\text{sp}}{\text{So}} \right) \). For such studies plants raised on artificially prepared slopes and bare plots draining down in collection compartments.

The vegetated and equal sized bare plots are exposed to natural rainfall or subjected to artificial showering as a result of which the soil and water from different plots rundown and get collected in respective reservoirs. The soil and water thus collected are weighed and chemically analysed for nutrients.

A few species commonly growing on river Ganga at Varanasi were tested for soil Cv under natural as well as artificial showering in a garden experiment (on sloping plots prepared by Ganga bank soil) (Ambasht 1970). The dense fibrous roots of Cynodon dactylon, Saccharum benghalensis and Cyperus rotundus conserved the soil between 91 to 96% in repeated trials. Dicotyledous tap rooted weeds like Euphorbia hirta and Alhagi camelorum showed Cv between 12-30% only. It is found that even when the shoot was clipped the Cv values of grasses remained high due to persistent binding effects of the interwoven roots. Similarly a number of additional species common on the banks of rivers Ganga, Varuna and Gomati were tested (Ambasht, Singh and Sharma, 1984) and it was found that Phyla nodiflora a dicot weed forming a mat like protective cover and rooting at nodes of the trailing stem conserved 93.8% soil while the grass Digitaria adscendens conserved 87.6%. It is a common knowledge that a good ground cover affords higher infiltration of water and less runoff while on bare conditions runoff is higher. The water Cv of Cynodon dactylon, Phyla nodiflora, Cyperus rotundus, and Digitaria adscendens are found to be 74%, 72%, 71% and 65% respectively. Crotalaria medicaginea a dicot weed has the soil Cv of 52% and water Cv of 59%. The plant cover of Cynodon dactylon allowed 21% of the rainfall water to flow down the sloping plot whereas from bare plot in the same treatment runoff was 81.6%. Similarly the other efficient soil binder species also increase infiltration considerably.

In the watershed of Chandraprabha river in Varanasi district, field experiments for soil, water and nutrient conservation in Heteropogon contortus and Bothriochloa pertusa dominated savanna were tested by making soil and water runoff collections from vegetated and equal sized adjacent bare plots after rainfall events for twelve months (1977-78) Ambasht (1985). The water runoff from plots were around 30% of the total rainfall while from bare area it increased to around 70%. The soil conservation value of the natural communities, stabilized under protection against grazing, was around 97% as would be evident from the fact that soil loss from these savanna sites were only a little less than 2 tons ha\(^{-1}\) yr\(^{-1}\) as compared to 60 tons or more ha\(^{-1}\) yr\(^{-1}\) from the scraped bare plots.

The nutrient losses are both through the soil erosion and water runoff. These natural communities due to their high soil and water Cvs also showed a high nutrient trapping capacity or high nutrient Cvs. Rainfall during the year of field study was 1425 mm and with rain water the input of nitrogen was 8.7 kg ha\(^{-1}\) yr\(^{-1}\) and of phosphorus 0.65 kg ha\(^{-1}\) yr\(^{-1}\). The total annual loss of nitrogen and phosphorus were 4.27 kg N ha\(^{-1}\) yr\(^{-1}\) and 0.28 kg P ha\(^{-1}\) yr\(^{-1}\) from vegetation covered and 109 kg N ha\(^{-1}\) yr\(^{-1}\) and 7.7 kg P ha\(^{-1}\) yr\(^{-1}\) from scraped plots. Thus the nutrient Cvs in protected field conditions were very high (96%). Lowrance et al. (1984) have regarded riparian vegetation as efficient remover of nutrients from subsurface flows, Verry and Timmons (1982) in their study of a riparian peatland of a forested watershed revealed that 36-60% of annual nutrient inputs were retained by streamline vegetation. Petterjohn and Correl (1986) have reported 89% nitrogen removal by a riparian forest in Maryland, USA. Considerable uptake of phosphorus by vegetation in a waste water receiving wetland is observed at Florida, USA by Boyt et al. (1977). Schwer and Clausen (1989) on a vegetated ‘filter strip’ found retention of 89% phosphorus and 92% nitrogen.

Corridor species, besides good conservers are also good harvestors of toxic heavy metals. Lyngby and Brix (1982) have noted that the trace metal contents like copper, lead and zinc in corridor vegetation reflects their concentration in the mud. Srivastava and Ambasht (1990) have found as high as 1875 \(\mu g/g\) of iron accumulation in Polygonum amphibium in industrially polluted waters of Rihand at Obra (Sonbhadra).
From the above findings it is concluded that river corridors are highly dynamic but fragile ecosystems and their stability, quality, usefulness and sustainability is dependent upon the preservation of biodiversity, maintenance of strips of corridor vegetation, regulated grazing and anthropogenic pressures, controlled discharge of pretreated effluents.

The role of plant cover in conserving the soil water and nutrients studied by the author and his students for Ganga basin around Varanasi proves their effectiveness.

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