Relevance of Ecosystems in Integrated Water Resources Management

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IWRM AND SUSTAINABLE DEVELOPMENT

Integrated Water Resources Management (IWRM) is a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic, environmental and institutional objectives (Fig 1).

The principles of IWRM evolved at the Dublin Conference (1992) are:

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment;
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers;
3. Women play a central role in the provision, management and safeguarding of water; and
4. Water has an economic value in all its competing uses and should be recognized as an economic good.

Though all these principles are relevant in the context of sustainable development of other natural resources also, water is a common factor in the sustainable development of all these resources. The key issues to be analysed in the context of water are: (i) growing water crisis and the need for urgent action; (ii) water governance crisis and associated factors; (iii) securing water for people; (iv) securing water for food; (v) gender disparities in the sector; and (vi) protection of vital ecosystems. The present lecture focuses on IWRM and ecosystems.

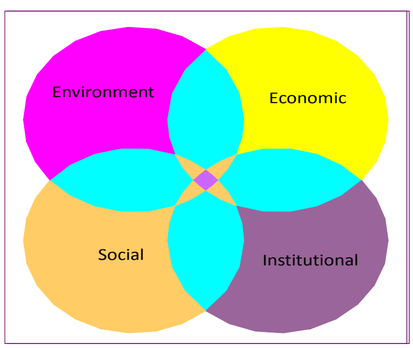

Fig1: Sustainable development: action within the spheres of environmental management and economic, social and institutional development

ECOSYSTEMS IN THE CONTEXT OF IWRM

The ecosystems within a river basin can be broadly classified into terrestrial and aquatic. For convenience of treatment in the context of a river basin, these can be classified into upstream and downstream ecosystems.

The terrestrial ecosystems both natural like forests and grasslands and manmade like agricultural and urban systems contribute considerably to the hydrologic regime and the water management of the river basin. In fact the ecosystems have their role in soil, water and biomass management of a watershed/ river basin. When compared to the aquatic ecosystems, terrestrial systems are comparatively dry from the point of view of hydrologic regime, rich as a biochemical source and low to medium in net primary productivity. Aquatic ecosystems are often flooded with water serving as a sink for bio-chemicals, with low primary productivity. On the other hand, wetlands are usually found at the interface between truly terrestrial ecosystems (such as upland forests and grasslands) and aquatic ecosystems (such as deep lakes and oceans) making them different from each , but highly dependent on both (Mitsch and Gooselink,1986) . Wetlands are often termed as ecotones to which materials are exported. The wetlands are intermittently or permanently flooded; these ecosystems serve as source, sink and transformer and their net primary productivity is generally high (Fig 2). The coastal ecosystems, especially coastal wetlands, are very much dependent on the water, sediments and biochemical transport from upstream reaches. These to a very great extent depend on the characteristics and the state of management of the upstream ecosystems and their communication with the sea, depending on the particular case.

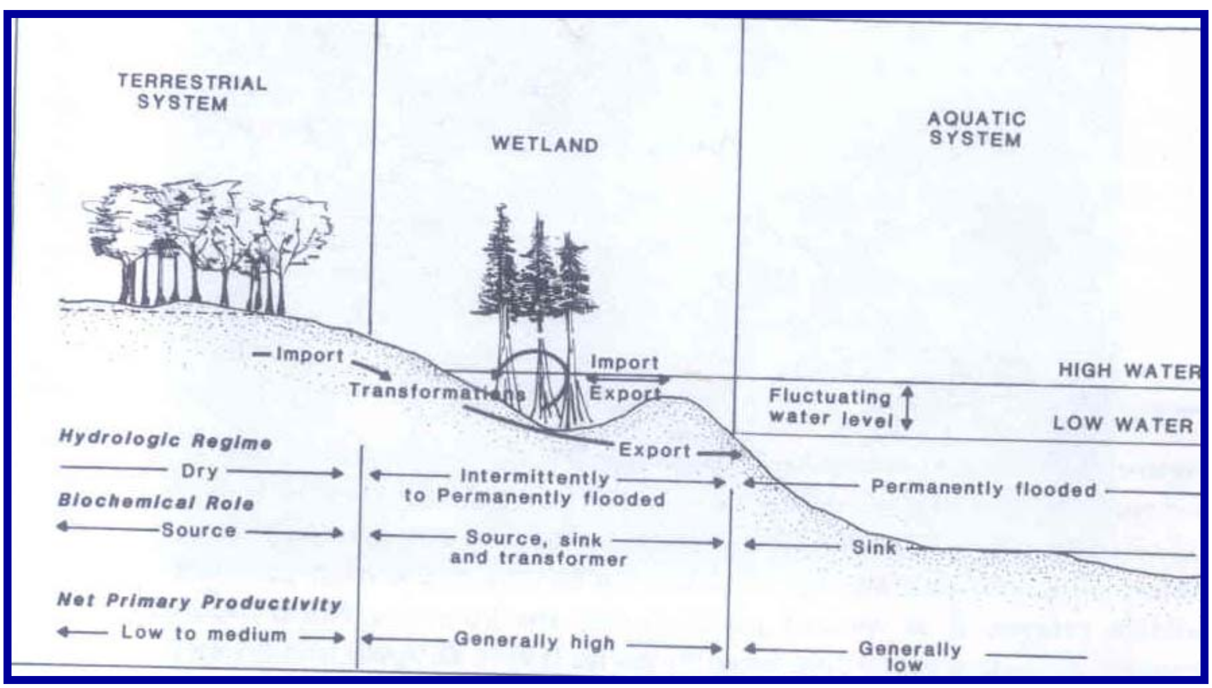

Fig 2: Hydrologic regime, biochemical role and primary productivity of terrestrial, aquatic and wetland ecosystems

The water balance based on blue-green water, upstream-downstream requirements and human – ecosystem needs will depend on the conservation and management of different ecosystems. The lecture covers only five generic systems, namely forests, cultivated and urban ecosystems, inland wetlands and coral islands.

The terrestrial ecosystems on the upstream of a river basin are important in the context of rainwater harvesting, groundwater recharge and for maintaining the stream flows during the lean season. Some of these contribute to food production, urban needs and biodiversity. Aquatic ecosystems are important from the point of view of food, fuel, medicinal plants, timber and biodiversity. Above all, these are important because of their recharging abilities, conservation of water and flood containing capacity. Therefore, this inter-connected web of terrestrial and aquatic ecosystems has to be conserved properly to serve as an 'environmental reserve' and to achieve this, scientific water management is necessary. IWRM, aiming at holistic approach or ecosystem approach, is important in the context of ecosystem conservation and management.

ENVIRONMENTAL RESERVE: FOREST ECOSYSTEM

Among the hydrologic functions of vegetal cover are: breaking the impact of rainfall; direct interception of a part of precipitation by the aerial portions of the plants; dissipation of soil moisture by transpiration; reduction in the loss of soil moisture by evaporation; binding the soil against erosion; and holding some moisture by the 'blotter' effect of litter (FAO, 1962).

The influence of vegetation upon infiltration and soil water storage is due to the effect of organic matter on and in the soil and to plant roots. Repeated measurements have shown a positive correlation between the quantity of organic matter present in soil and its water holding capacity. The studies in different parts of the world have shown that the water absorption capacity reduces due to forest fires and heavy use and trampling of soil. Such disturbed soils showed one-third of the rate of absorption of undisturbed forests.

Channels left by decayed roots also perform an important function in percolation and storage of water. Also, the growing tips force a way into minute cracks in the soil granules and through small passages between soil grains. When the roots die, they soon decay, leaving channels through which water may pass through the soil. The soil under relatively undisturbed forest and range cover is home of much animal life. Many animals, including most of the rodents and insects, dwell or borrow in soil. Fungus mycelia grow grow downwards and increase the lines of cleavage. These activities are conducive to the development and maintenance of a relatively high water-absorptive capacity. Any modification to the plant cover and surface soil by cultivation, burning, or over-grazing induces conditions favorable to the optimum development of these soil fauna and flora and results in a reduction in the capacity of the soil to take up water.

Water occupies the soil in three forms: hydroscopic (held in small pore spaces), capillary (tightly held on to soil particles) and gravitational (drained from larger pore spaces). Precipitation reaching the soil surface, which does not infiltrate or pond in small depressions, moves downhill over the soil surface as overland flow (Hewlett and Nutter,1969). Vegetation increases surface roughness, and litter particles on the soil surface form small dams and obstructions which slow down the velocity of overland flow and discourage concentration in rills and gullies.

Soil erosion may be broadly classified into: sheet erosion and channel erosion – the latter includes rill and gully erosion. Vegetation acts to reduce erosion by slowing down the velocity of water flowing over the soil surface. Some erosion is caused by overland flow; the effects of vegetation in reducing and retarding overland flow also operate to reduce erosion. Moreover, interception by canopy reduces the energy of rain drops.

Studies were conducted in three clusters of watersheds in the forest areas of the western ghats of south-west India to understand the role played by the forests in water management of this humid tropical region with an average rainfall of 3000 mm. Three watersheds, one each with 60% and more canopy, between 30 and 60% of canopy and less than 30% canopy constituted each of the three clusters ; the clusters were selected at Muzhy in Kozhikode and Vazhani and Chimoni in Trichur districts of Kerala. Based on the data collected from the field, following general observations were made:

(i) The annual and monsoon runoff from a unit area of exploited watershed (less than 30% canopy) is more than that of other two in all the individual clusters; discharge from dense forest watershed (more than 60% canopy) lasts longer than the other watersheds after the monsoon season; the runoff coefficient with respect to rainfall is very high for exploited watersheds; the unit hydrographs of one-year duration show that lag time subsequent to a storm in a dense watershed is 35% more than that of the exploited watershed (Fig 3).

(ii) Based on the observations of throughfall and stemflow, it is seen that the average interception from a typical mixed forest watershed of western ghats is 10% of the rainfall.

(iii) The quantification of bed load accumulated at the weir sites on the downstream of the watersheds shows that the bed load accumulation at the exploited watersheds is more than six times of that of dense forest watersheds (Fig4).

(iv) In all the seasons at all the depths considered, maximum soil moisture was observed in the dense forest watershed followed by other exploited watersheds in each of the clusters.

(v) The water balance study indicates that the deficit during the summer months of January-May is more in the exploited watersheds of each cluster than the forest watersheds (James et al, 1987).

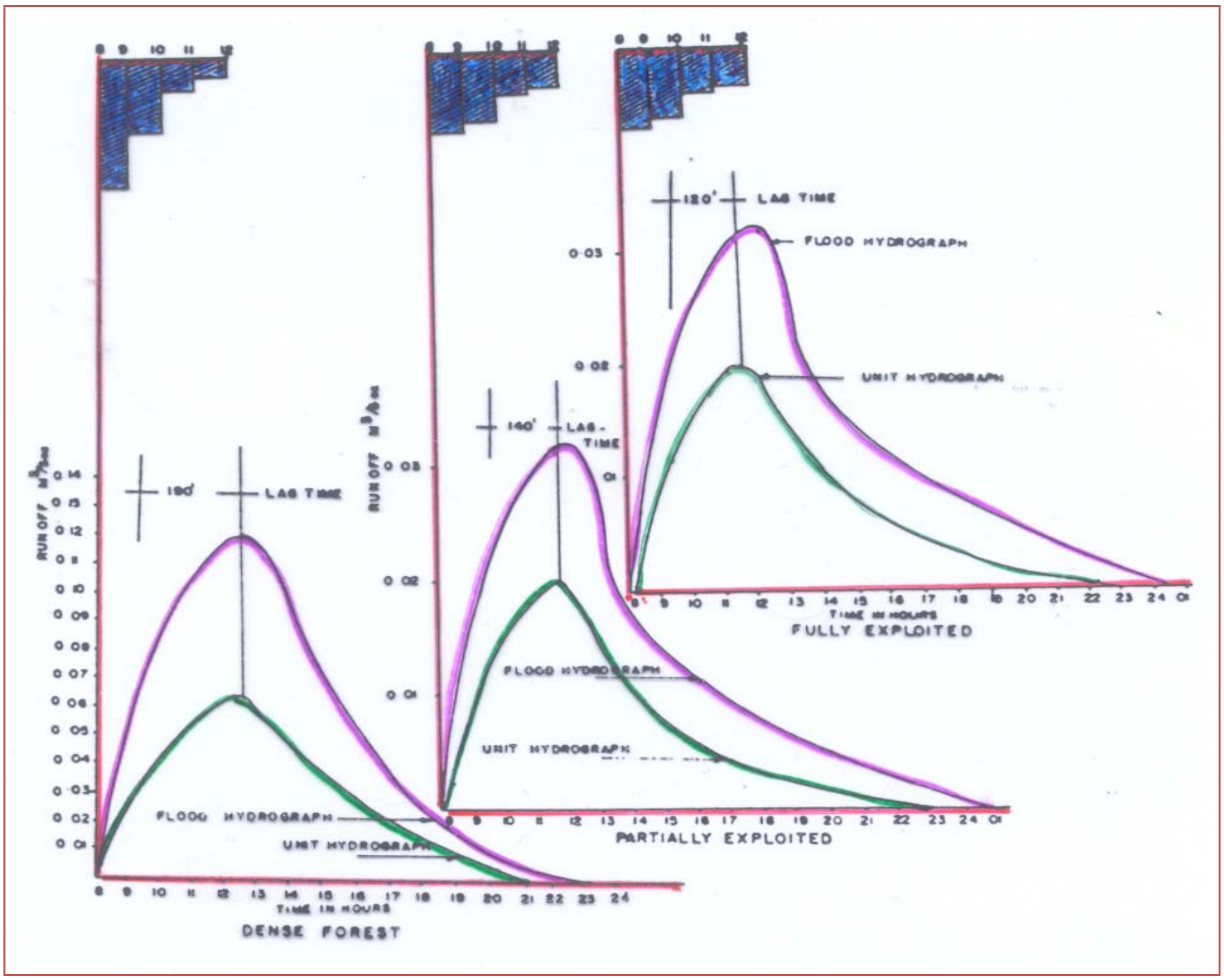

Fig 3: 1-hr Unit hydrograph for dense forest (>60% canopy), partially exploited (30-60% canopy) and fully exploited (30% canopy) watersheds of the Western Ghats, Kerala (India) showing the differences in lagtime

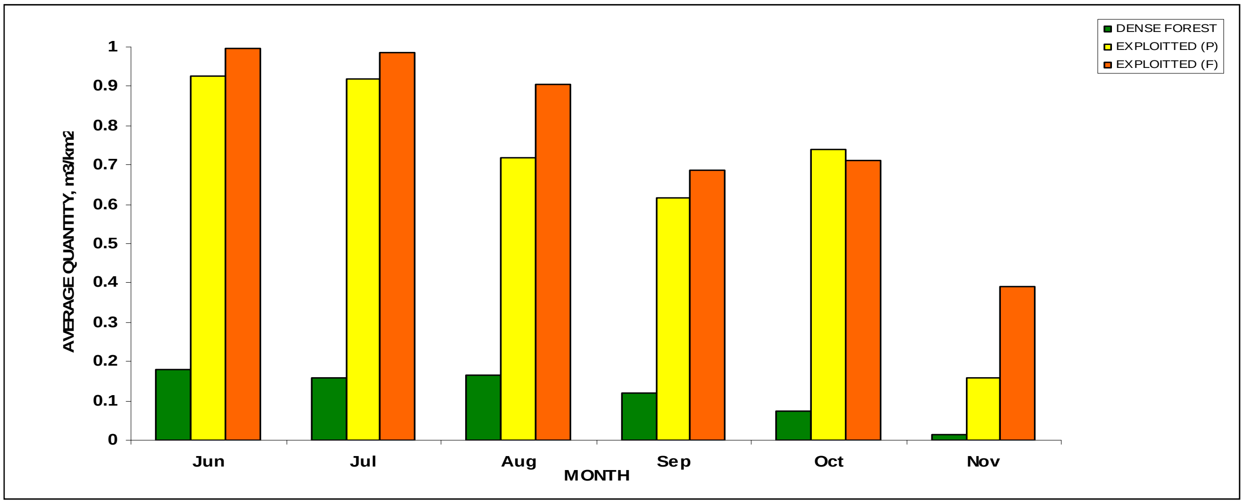

Fig 4 Bed load accumulated during the monsoon months at the outlets of different watersheds

AGRICULTURAL ECOSYSTEM: LAND-WATER LINKAGES

There should be a shift from the present land/water dichotomy, apparent in UNCED Agenda 21, towards an integral concept of the land as a system traversed by water,with land use depending on access to water (among other factors) and at the same time, affecting the passing water in its pathways, seasonality, yield and quality.

Man depends on access to water in the landscape for several parallel functions. These include human and community health and well-being; biomass production; other forms of socio-economic production; the maintenance of habitats for ecological protection; and the transport of soluble and solid materials such as nutrients, pollutants and sediments. The water passing through a landscape is influenced by human activities in that landscape, and may therefore present problems which must be anticipated and met by mitigating measures (FAO, 1993).

Water may sustain land use but may also be a constraint on land use and socio-economic and biomass production. At the same time, land use influences water characteristics by its partitioning of incoming rainfall between the vertical return flow to the atmosphere as evaporation and evapotranspiration, and the horizontal flow to aquifers and rivers, classified as 'blue water'. The various functions listed herein, related to human activities, also affect both physical and chemical characteristics of water, as shown below (Falkenmark, 1993):

A. Atmospheric Qualities

- Atmospheric moisture supply: rainfall, evaporation, dew formation
- Atmospheric energy for photosynthesis: temperature, daylength, sunshine conditions.
- Atmospheric conditions for crop ripening, harvesting and land preparation: dry-spell occurrence
- Liability to atmospheric calamities: hazard of tornadoes, hailstorms, etc

B. Land Cover Qualities

- Value of the standing vegetation as "crop" (e.g. timber)
- Value of the standing vegetation as germ plasm (biodiversity value)
- Value of the standing vegetation as protection against soil degradation
- Value of the standing vegetation as protection for crops and cattle against adverse atmospheric influences
- Hindrance of vegetation at introduction of crops and pastures: the land "development" costs

C. Land Surface Qualities

- Surface receptivity as seedbed: the tilth condition
- Surface treadibility: the bearing capacity for cattle, machinery etc
- Surface limitations for the use of implements (stoniness, stickiness, etc.): the arability
- Spatial regularity of soil and terrain pattern: the degree of freedom at determining the size and shape of fields with a capacity for uniform management
- Accessibility of the land: the degree of remoteness from means of transport. Surface water storage capacity of the terrain: the presence or potential of "waterholes", on-farm reservoirs, bunds, fish ponds, etc
- Surface propensity to yield runoff water (for local water harvesting or downstream water supply)
- Accumulation position of the land: degree of fertility renewal and /or crop damaging by overflow or over blow

D. Soil Profile Qualities

- Physical soil fertility: the net moisture storage capacity in the rootable zone
- Physical soil toxicity: the presence or hazard of waterlogging in the rootable zone (i.e. the absence of oxygen or the excess of CO_2).
- Chemical soil fertility: the availability of plant nutrients
- Chemical soil toxicity: salinity or salinization hazard; excess of exchangeable alumina
- Biological soil fertility: the N-fixation capacity of the soil biomass; the microbial

capacity for the transformation of fresh soil organic matter into readily available plant nutrients
- Biological soil toxicity: the presence or hazard of soil-borne pests and diseases

E. Substratum Qualities

- Groundwater level and quality in relation to (irrigated) land use
- Substratum potential for water storage (local use) and conductance (downstream use)
- Presence of unconfined freshwater aquifers
- Substratum (and soil profile) suitability for foundation works (buildings, roads, canals, etc.)
- Substratum (and soil profile) as source of construction materials

For his use of natural resources, man must manipulate the landscape that contains them. Natural laws operating in that landscape produce side effects, often designated as 'environmental impacts'. For instance, changes in land use alter two 'joints', or boundaries in the soil profile that determine the partitioning of incoming water. The first of these boundaries, at the soil surface, serves as a division between over land flows and infiltration. The other, in the root zone, is a partition between the "green water" accessible in the root zone, later to be used in plant production, and the surplus water that flows on to recharge aquifers or other water bodies. The land based phases of the hydrologic cycle are given in Fig 5.

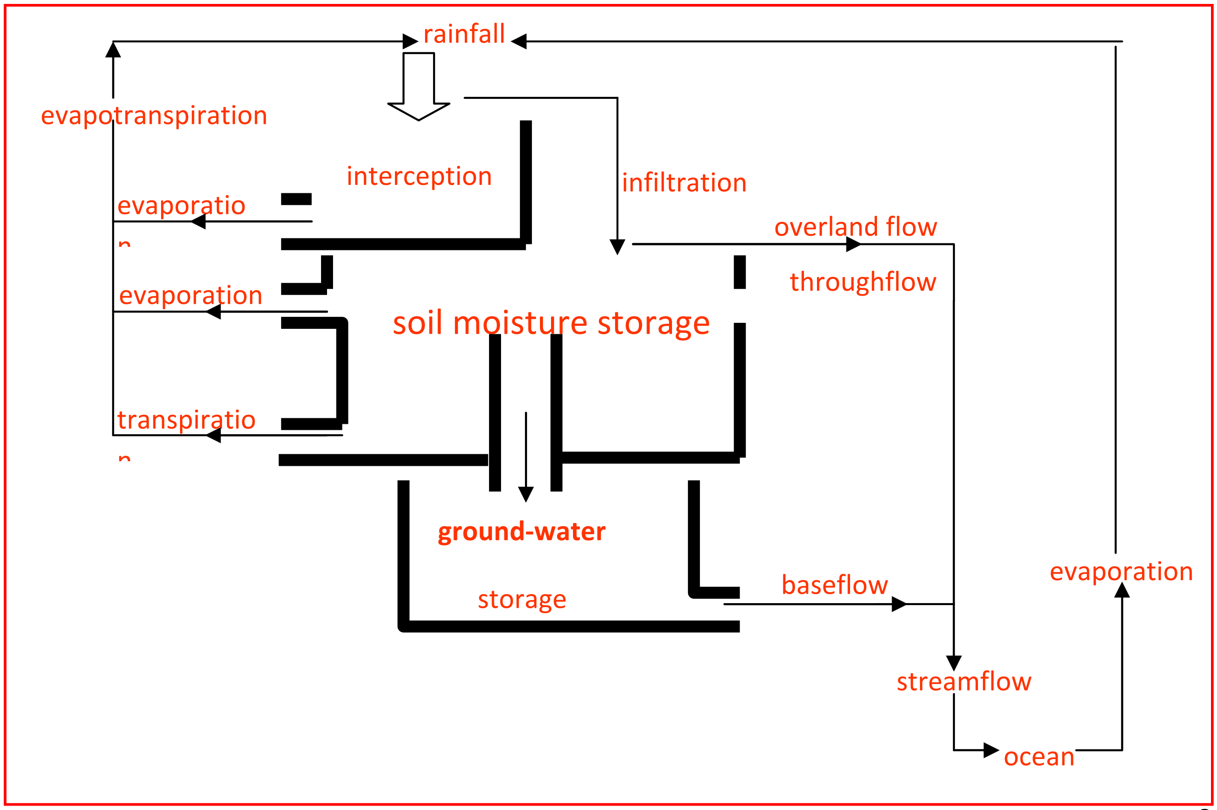

Fig 5: Land-based phases of the hydrologic cycle

The characteristics of land and anthropogenic activities will have an impact on the land-based phases of the hydrologic cycle. The human interventions cascades through the water cycle, producing secondary effects on terrestrial, aquatic and marine ecosystems, and thus the sustainability of the environment and of natural resources development and management. The resulting problem profiles are quite different in different hydroclimatic regions - their occurrence and weight as well as severity.

There has been a lack of understanding on the linkages between the hydrological, geomorphological, and pedological processes and the plant nutrients dynamics at landscape level, as well as the implications of soil and water resources conservation and development in the whole river basin environment.

Those involved in different sectors of resources development looked at the land units differently. For example, soil specialists gave much weight to soil profile characterization and classification and their mapping work centered on these classification units. Hydrologists had their own methodologies, concentrating on the lateral dynamics of water resources, and rarely using landscape units as unifying criteria. Irrigation and drainage specialists believed in spatial units on the basis of rigid observations without considering soil-water properties. Soil fertility and fertilizer promotion specialists rarely considered soil classification criteria and soil mapping units and followed a grid system. Vegetation and forestry specialists also did not pay attention to land units. Civil engineers had their own sampling techniques disregarding information available with other disciplines. All these mono-disciplinary activities often resulted in a tangle of boundaries of land management units when maps of field information for different natural resources had to be combined.

Physical geographers have been trying all along to advocate a landscape and catchment approach. However, geomorphologists were often in disagreement on a unified approach; several fancy schemes on geomorphodynamics were developed by them but not one single classification scheme on landforms to be understood by non- specialists on the subject. However, the "catena" concept of Milne, "land system" approach of Australia, "geo-pedo-morpho-hydrological" and "landscape-ecological” concepts of Trall, Tricart and others (Vink 1986) are worth mentioning.

The degree of holism hinges on the definition of "Land"; one such definition is given below:

" Land is a delineable portion of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associate groundwater and geohydrological reserve, the plant and animal populations, the human settlement pattern and the physical results of past and present human activity (terracing, water storage or drainage structures, roads, etc)" (Sombroek, 1994).

In this holistic approach, a unit of land has both a vertical aspect - from atmospheric climate down to groundwater resources, and a horizontal aspect - an identifiable repetitive sequence of soil, terrain, hydrological and vegetation or land use elements ("landscape", "land unit", or "terroir" units). Mineral resources and deeper geohydrological resources (confined aquifers) would, however, be excluded from land attributes.

It is possible in this definition of Land to integrate all compartments vertically: from groundwater-related qualities through qualities of soil profile, soil surface, slope position and vegetation cover, to overhead climatic qualities. It is also necessary to integrate all aspects horizontally at the landscape level, in which approach physical geographers take into account typical, micro-geographically repetitive elements of terrain, top or plateau, scarp or upper slope, main slope, lower slope or springline, bottomland or flood plain, with their mutual influences whether natural or under current land use. This influence can be in the sense of internal hydrology (for instance, rainfall traversing into soil of the plateau and surfacing at the springline, including the lateral movement of chemical substances such as salts and silica), or the surface transport of soil material through erosion from upper slopes and accumulating in the bottomland or flood plain (Falkenmark 1993). Both these influences can be detrimental or positive at the receiving end, depending on the rate of transport and the prevailing climatic conditions. The lateral influence also relates to chemical soil fertility. Nutrients may be transferred downslope by natural processes, or from outlying land to arable fields near homesteads in traditional farming systems.

The watershed is the natural integrator of all the hydrologic phenomena pertaining to its boundaries, and as such, it is a logical unit for planning optimal development of soil, water and even bio-resources. There has been a tendency to focus integrated management of land, water and agriculture based on a small watershed (Fig 6). From the hydrological point of view, a distinct characteristic of a small watershed is that the effect of overland flow rather than the effect of channel flow is a dominating factor affecting the peak runoff. A few case studies from India are presented in the lecture.

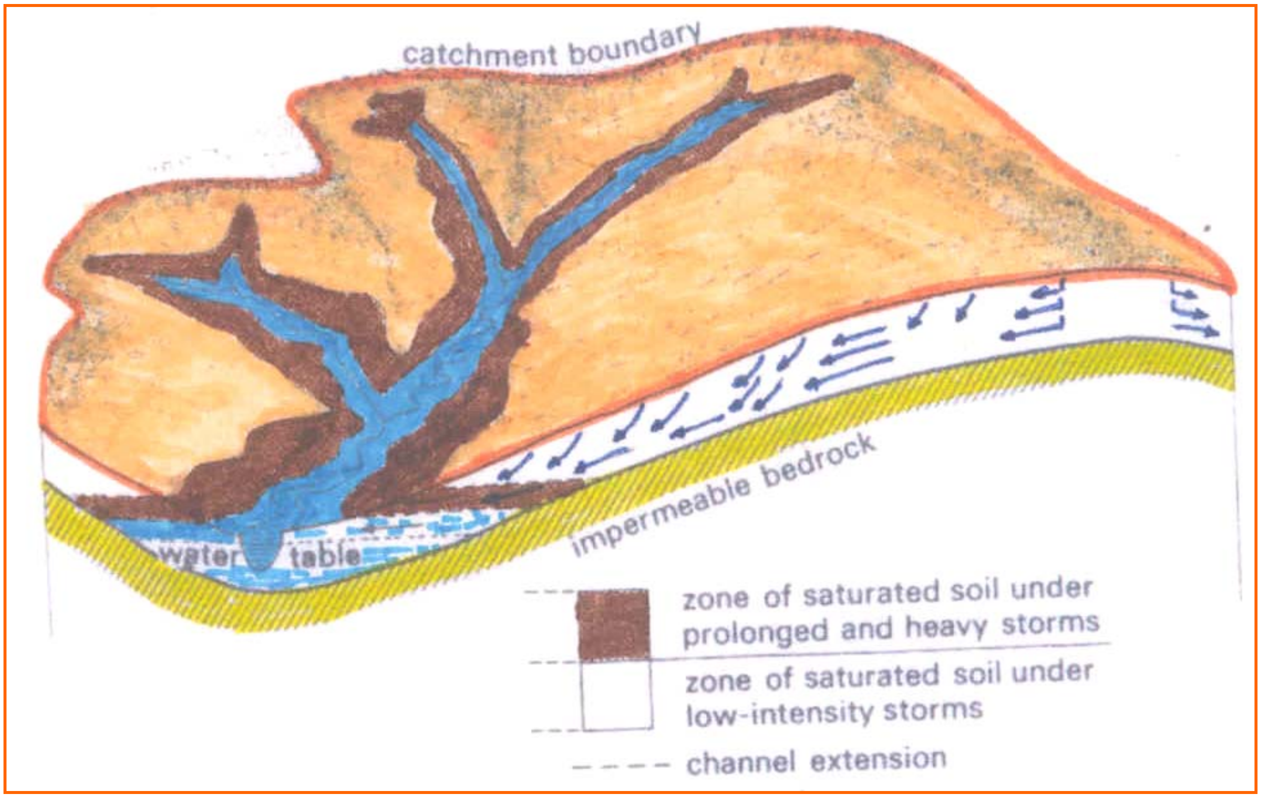

Fig 6: Effect of a rainstorm on the watershed

POPULATION PRESSURE: URBAN ECOSYSTEM

As the land surface is developed for urban use, a region is transformed from the natural state to a totally manmade state. New structures add large amount of impervious areas to the watershed, which in general increase slopes and considerably diminish the water storage capability. As the area covered by structures approaches 100%, the amount of vegetation, natural surface and infiltration will all approach zero. A comparison of natural and urban watersheds is given in Fig 7. The improvements to the drainage system may reduce the lagtime (between the rainfall and peak runoff) of the hydrograph to one-eighth that of natural channels. The lagtime reduction, combined with an increased storm runoff resulting from impervious surfaces, increases the flood peaks by a factor that ranges from two to nearly eight (ASCE/UNESCO,1998).

Fig 7

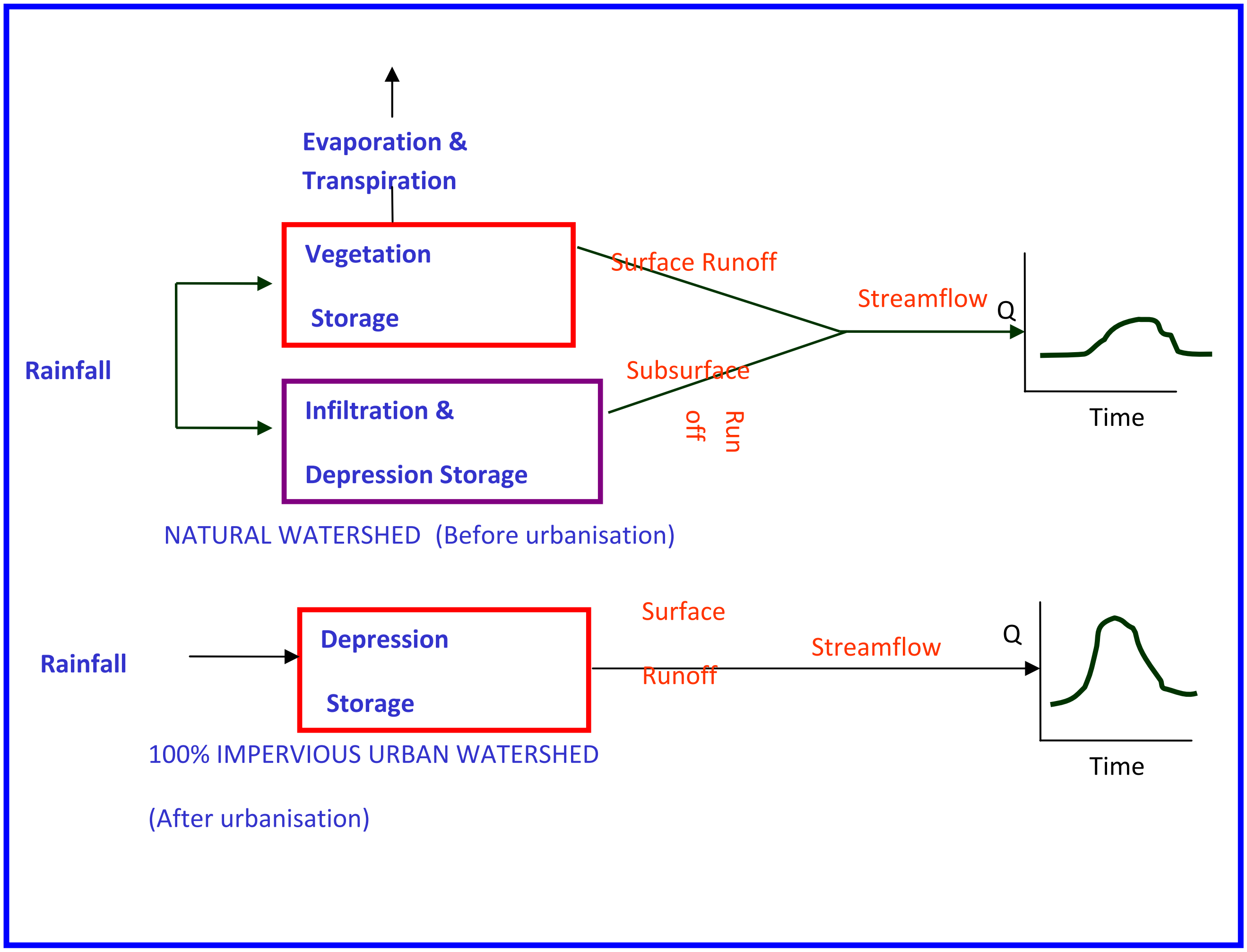

Fig 7: Hydrograph shapes - natural and urban watersheds

As an area becomes impervious, infiltration is reduced and subsurface runoff is lost to surface runoff. The volume of water lost by an urban basin to surface runoff would directly depend upon its percent of imperviousness. Several case studies are available on these aspects. In exceptional cases, baseflow may increase in urban streams due to the watering of lawns and gardens, sewage effluents, and deliberate transfers of water from other watersheds (Johannus and Haagsma, 1995). The sediment in streams results from erosion of soils by overland (sheet) erosion, and by scouring of ditches and stream channels. Within urban areas, increase in storm runoff adds high peaks of energy which augment the natural erosive forces and greatly accelerate erosion. Any unprotected ground surface may easily be scoured. Streams are filled with sediment-laden water and their cross-sectional areas may be enlarged. This process produces several changes in the physical and biological characteristics of the stream channel. These changes include deposition within the channel, destruction of flow and increased flooding, shifting configurations of the channel bottom, blanketing of bottom dwelling flora and fauna, alteration of the flora and fauna as a result of changes of light transmission and abrasive effects of sediment, and alteration of species of fish as a result of changes produced in the flora and fauna upon which the fish depend.

High suspended sediment concentrations are probably indicative of: (i) land surface disturbance somewhere in the watershed; (ii) accumulation of dust and the first flush effect; and (iii) scouring of the stream channel itself. Several researchers have shown that without a doubt, nowhere in the process of urbanisation is erosion so violent as in the construction phase.

The entry of pollutants into a flowing stream sets off a progressive series of physical, chemical and biological events in the downstream waters. Their nature is governed by the character and quantity of the polluting substance. If one were to take dissolved oxygen measurement at various points along a river flowing downstream, one would derive a dissolved oxygen sag curve. From before the point of sewage entry (at mile 0) to the 15th mile downstream, generally the bacterial composition proceeds mainly by aerobisis. From the 15th mile to about 30th mile, bacterial decomposition occurs by means of anaerobisis; after this point, aerobic conditions return.

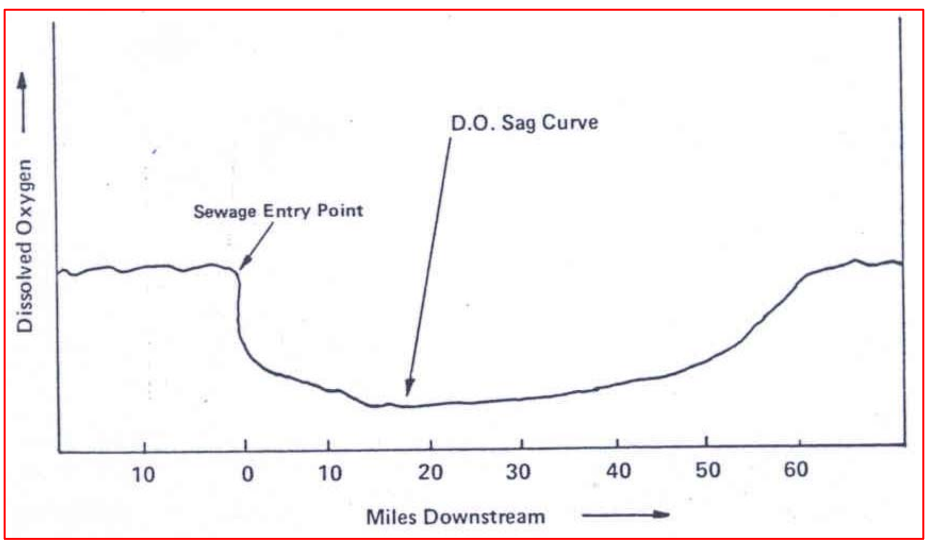

Fig 8: DO sag curve of an urban watershed

The urban landuse patterns can be divided into five principal settings: (i) construction, (ii) industry, (iii) commerce, (iv) streets and roads, (v) residential sections. Construction activities themselves can be divided into several phases. Many industries have a significant effect on quality of air, stormwater, streamflow, and groundwater. Exposed surfaces may accumulate pollutants generated by automobile traffic, litter, dustfall, and spills. Automobiles contribute to several pollutants. Hospitals, markets and residential areas also contribute to the pollution load, both chemical and biological, of the urban areas.

The clearing of vegetation decreases the capacity of the watershed to capture moisture, increasing the runoff. The loss of vegetation also destabilises stream bank vegetation and reduces the shade produced by the canopy. Increased solar pollution raises stream water temperatures during the summer months, destroying the habitat of fish and disrupting the ecosystem. Conversion from predominantly vegetated landuse to urban uses may result in tremendous reductions in the absorption capacity of watersheds. The increased volumes of runoff also travel more quickly to surface waters, which in turn produce higher peak flows and velocities. Flooding may occur as flows exceed natural, designed, or available system capacities, threatening homes and business located along the stream. Pollutants such as oil, gas, fertilizers and pesticide adversely affect fish, wildlife, plants, and may impact on drinking water sources.

MODIFYING THE HYDROLOGIC REGIME: INLAND WETLANDS

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water intermittently or all through the year. Wetlands must have one or more of the three attributes: (i) atleast periodically, the land supports predominantly hydrophytes; (ii) the substrate is predominantly undrained hydric soil; and (iii) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year (Mitsch and gosselink, 1993). The wetlands can be broadly classified into inland fresh and saline as well as coastal fresh and saline areas (Fig 9).

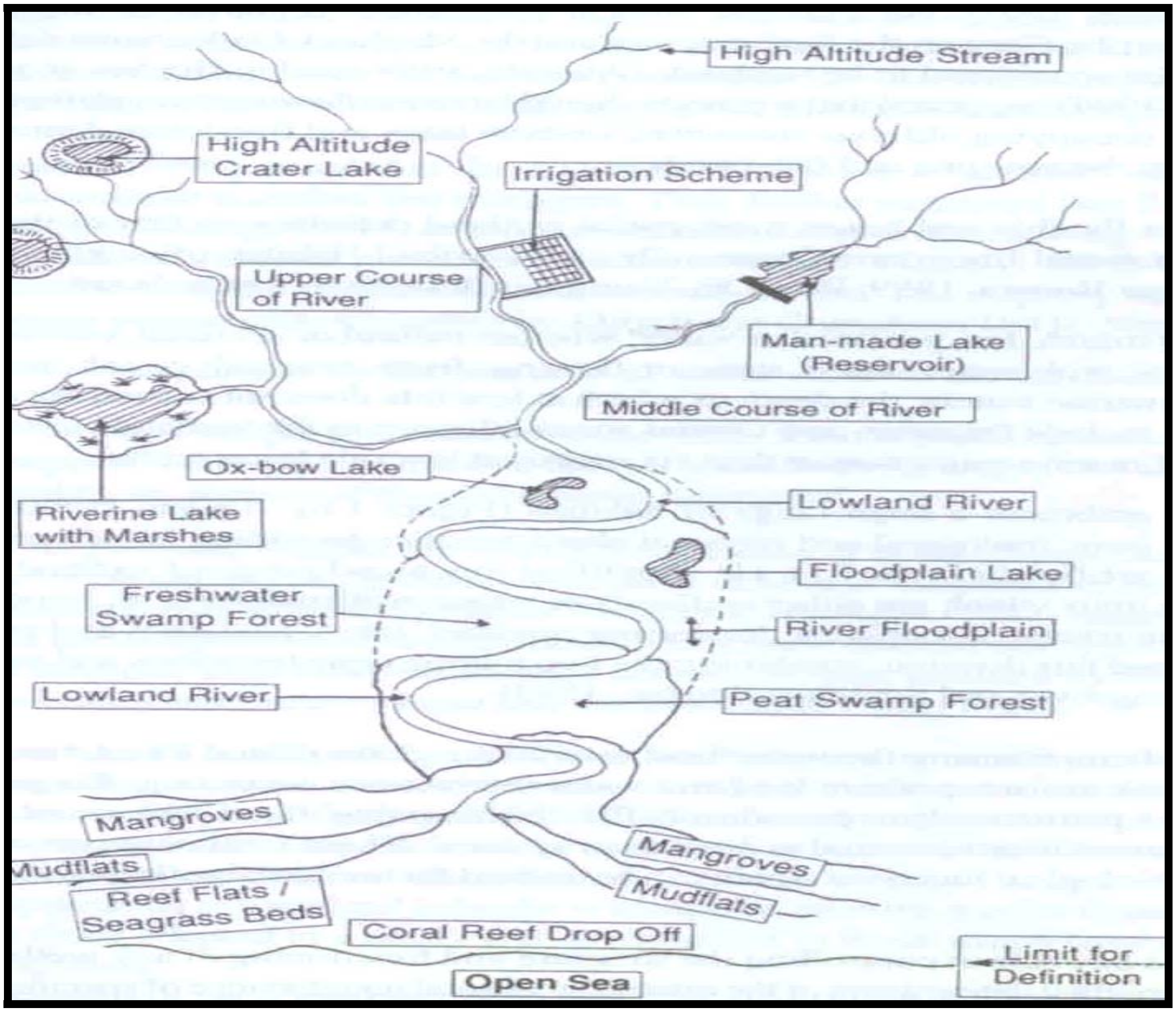

Fig 9: Wetland classification according to Ramsar Bureau

Wetlands are among the most important ecosystems of the Earth. On a short-time scale, wetlands are useful as sources, sinks, and transformers of a multitude of chemical, biological and genetic materials. They have been found to cleanse polluted water, prevent floods, protect shorelines and recharge aquifers. Furthermore, wetlands provide unique habitats for a wide variety of flora and fauna. Some scientists have rightly called the wetlands as the 'nature's kidneys'.

Hydrology is probably the single-most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. A conceptual model showing the direct and indirect effects of hydrology on wetlands is given in Fig 10. The hydrologic conditions can directly modify or change chemical and physical properties such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties and pH. Biotic control mechanisms of wetlands include peat building, sediment trapping, water-shading and transpiration. These processes decrease the frequency of floods, reduce erosion, and control evaporation.

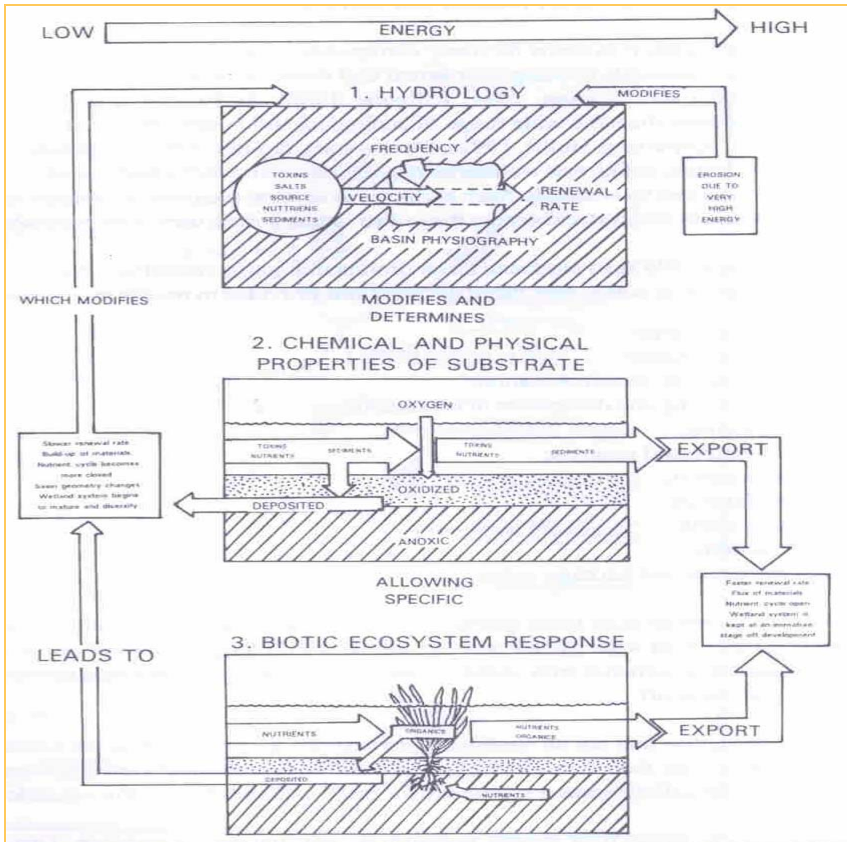

Fig 10: A conceptual model – impact of hydrology on wetlands

Hydrology leads to a unique vegetation composition but can limit or enhance species richness. Primary productivity is enhanced by flowing conditions and pulsing hydroperiod, and is often depressed by stagnant conditions. Organic accumulation is controlled by hydrology, through the influence on the primary productivity, decomposition, and export of particulate organic matter. Nutrient cycling and nutrient availability are both significantly influenced by the hydrologic conditions. Different species have different physiological response to flooding. Large trees show greater tolerance to flooding than do seedlings.

The important values and attributes of the wetlands from the IWRM point of view are: (i) containing the floods and regulating the flows (Figs 10 and 11); (ii) purifying the water; (iii) recharging the groundwater; (iv) maintaining the summer flows; (v) providing an aquatic ecosystem for biodiversity; and (vi) encouraging water sports and tourism.

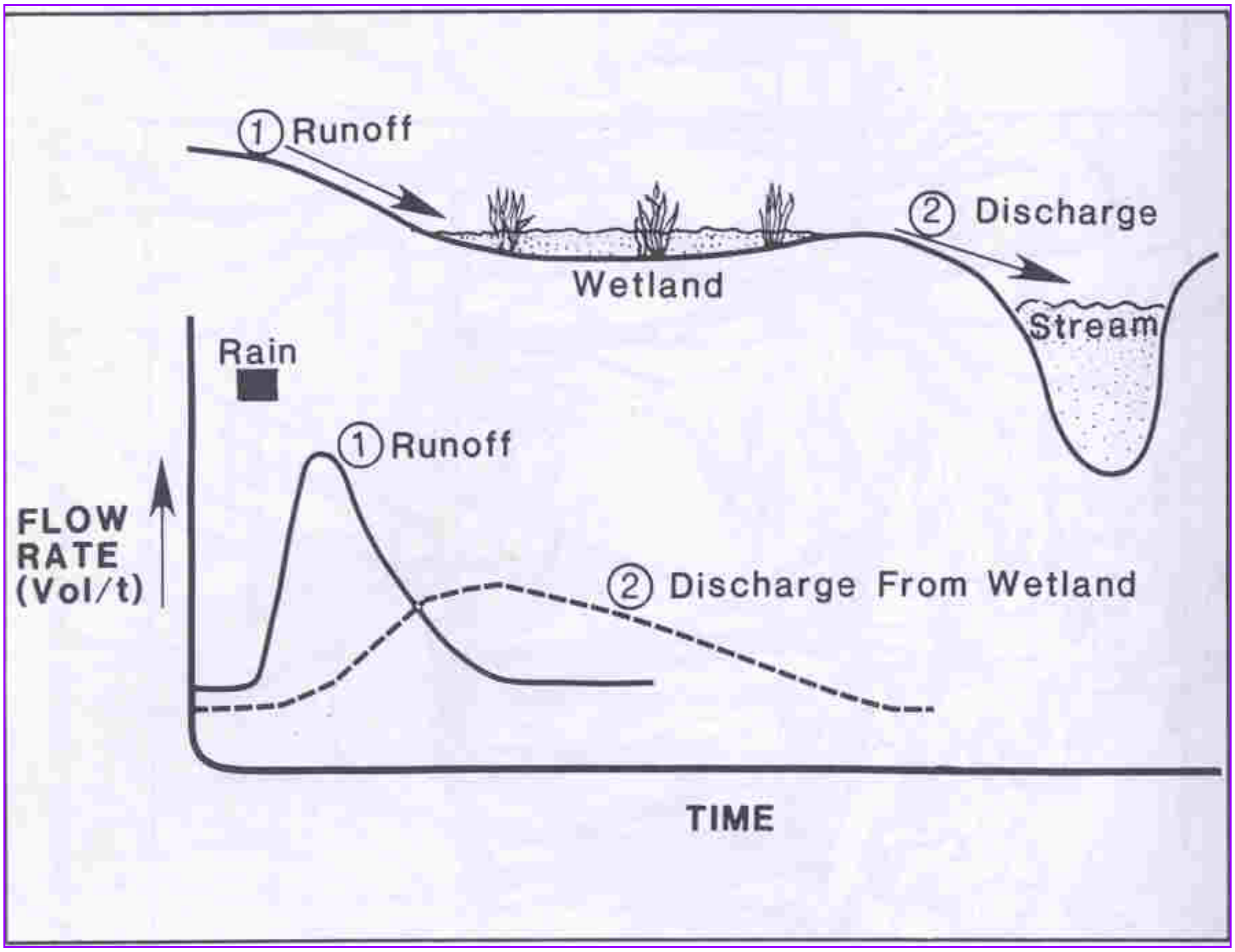

Fig 11: Role of wetlands in containing and regulating floods

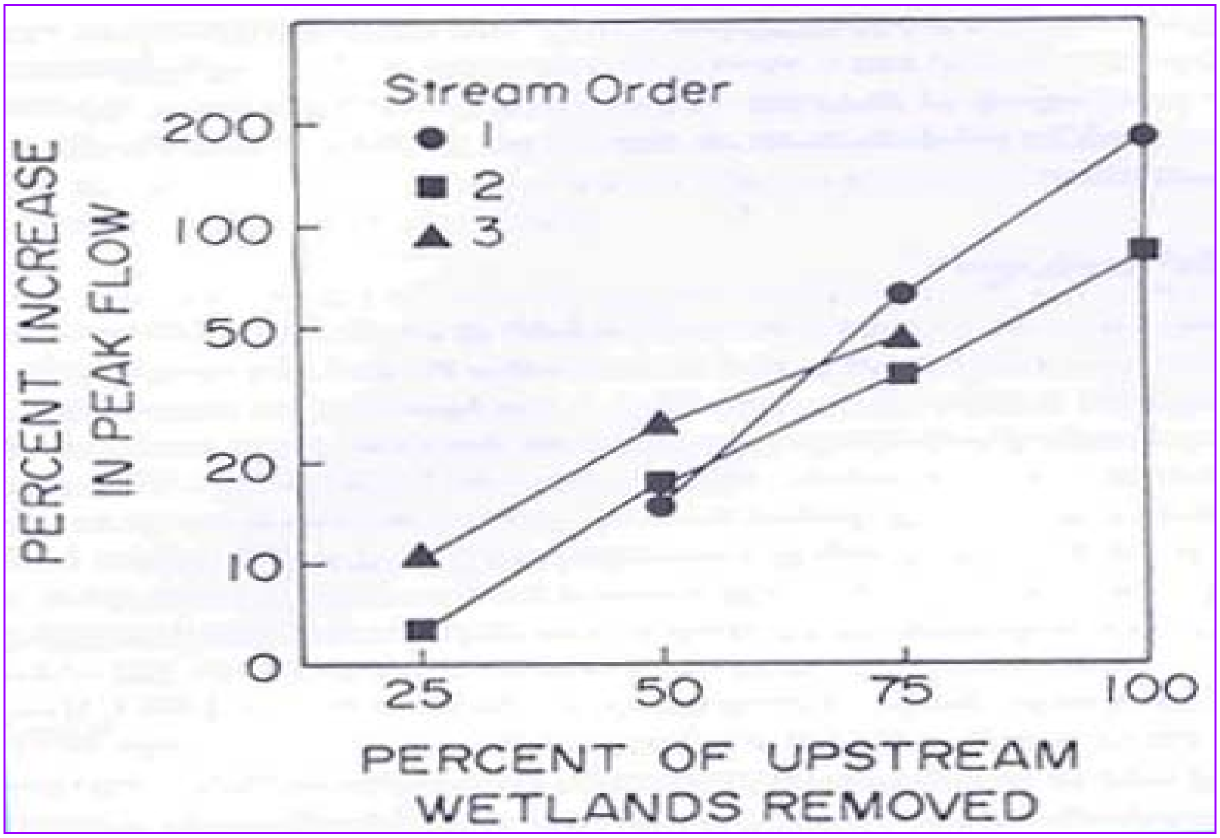

Fig 12: Increase in peak flows due to destruction of wetlands

FRESH WATER SCARCITY: ISLAND ECOSYSTEMS

Small coral islands of less than 5 square kilometer area like the ones in Maldives and Lakshadweep do not have fresh water sources to meet their requirements and those of the tourists visiting their islands. Often, there are no surface water bodies like streams and rivers. A limited quantity of water is available as groundwater for the utilization of the local population. The total population of 62000 people living in the 10 inhabited islands of Lakshadweep requires about 3.5 million litres of fresh water per day. This need is increasing day by day due to increasing population and changes in water use pattern. Due to high permeability of these coral islands and limited subterranean storage space above the mean sea level, a substantial portion of the infiltrated water percolated into the sea. The outflow coupled with the consumptive uses leaves only a fraction of the infiltrated water as an effective recharge to the shallow aquifer. The water in such shallow aquifers often gets contaminated by human wastes and other sources from the thickly populated areas in the islands.

A study of the islands of Lakshadweep showed that the total population in the 10 inhabited islands of an average area of less than 5 sq km is 62000. Most of them do not have proper sanitation facilities and 60% of the wells are within 10 m distance from the leach pits. Around 90% of the wells, main source of fresh water in these islands, are bacterially contaminated and this calls for frequent disinfection and sanitization of the wells of these islands. Bacterial contamination is at its peak in the rainy season – June-October. It is a matter of great concern that about 50% of the population suffer from stomach and intestinal disorders and skin diseases. A participatory project funded by India- Canada Environment Facility provided drinking water facility to 20% of the total population of Lakshadweep Islands (Fig 13).

Fig 13: Rainwater harvesting structures made out of ferrocement; more than thousand such structures were constructed in the island as part of a participatory project

In the coral islands, groundwater occurs under phreatic condition. Fresh groundwater floats as a lens over the brackish water overlying the saline water. The sea water is in hydraulic continuity with the groundwater and this is evidenced from the influence of tidal action in the wells of the islands. The depth of groundwater level varies from 1 to 5 m. The strategy for water management in the coral islands calls for control of water use, prevention of electrical lifting devices, sanitization of wells, more sanitation facilities, introduction of rain water harvesting structures, desalination plants wherever essential. Moreover, there is a great need to come out with policies and regulatory mechanisms along with creation of awareness among the local people and tourists. A separate strategy for water conservation of small coral islands has to be evolved to conserve these sensitive ecosystems (CWRDM, ICEF and LA,2006).

RECAP

The role of ecosystems in the context of IWRM has been discussed. Also, the importance of IWRM for conserving the ecosystems to function as 'Environmental Reserve' has been highlighted. The ecosystems covered are forest, agricultural, urban, wetland and island ecosystems.

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POINTS TO PONDER:

1 (a) What are the water conservation measures implemented in your residential area?

(b) Think over the indicators to be used to assess the success of a watershed development project in your area.

2 (a) Forests contribute to soil and water conservation, and even micro-climate within the ecosystem. Discuss.

(b) Can you suggest some strategies to conserve the forest ecosystems of you country/state?

3 (a) What are the components involved in urban watershed management?

(b) Do you remember an example where urban water management did not give desired results?

4. (a)What are the regulatory mechanisms required for conserving the wetlands of your area?

(b) Can you give a case study of successful wetland management from your country?

5 (a) Small island ecosystems have limited water sources. Can you justify this statement?

(b) Can you suggest some measures for water management of small coral islands ?