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Environmental impacts of irrigation development: A Review

Laxmi Devi, Email- laxmirani9937@ gmail.com

Abstract

Environmental impacts of irrigation are the changes in quantity and quality of soil and water as a result of irrigation and the ensuing effects on natural and social conditions at the tail-end and downstream of the irrigation scheme. The impacts stem from the changed hydrological conditions owing to the installation and operation of the scheme. Because irrigation systems deal with redirecting water from rivers, lakes, and underground sources, they have a direct impact on the surrounding environment. Some of these impacts include: increased groundwater level in irrigated areas, decreased water flow downstream of sourced rivers and streams, and increased evaporation in irrigated areas. Increased evaporation in irrigated areas can cause instability in the atmosphere, as well as increase levels of rainfall downwind of the irrigation. These changes to the climate are a direct result of changes to natural moisture levels in the surrounding atmosphere.

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Introduction

The current global context is conditioned by the growth of the world's population and the progressive and continuous deterioration of the environment. This creates the challenge of ensuring the supply of basic resources, such as food and water, and sustainable development , where water plays an essential role in the survival of human society and contributes to the provision of a wide range of services on which the wellbeing of society is based. However, water resources are subject to severe degradation due to many factors, such as the consequences of global climate change, alterations in the use of land, agricultural and urban expansion, and overexploitation due to economic development. In parallel with this degradation and overexploitation of ecosystems and water resources, the demand for the services supplied by these resources is expected to increase.

Potential environmental impacts of irrigation development

The expansion and intensification of agriculture made possible by irrigation has the potential for causing: increased erosion; pollution of surface water and groundwater from agricultural biocides; deterioration of water quality; increased nutrient levels in the irrigation and drainage water resulting in algal blooms, proliferation of aquatic weeds and eutrophication in irrigation canals and downstream waterways. Poor water quality below an irrigation project may render the water unfit for other users, harm aquatic species and, because of high nutrient content, result in aquatic weed growth that obstructs waterways and has health, navigation and ecological consequences. Elimination of dry season die-back and the creation of a more humid microclimate may result in an increase of agricultural pests an plant diseases.

Large irrigation projects which impound or divert river water have the potential to cause major environmental disturbances, resulting from changes in the hydrology and limnology of river basins. Reducing the river flow changes flood plain land use and ecology and can cause salt water intrusion in the river and into the groundwater of adjacent lands. Diversion of water through irrigation further reduces the water supply for downstream users, including municipalities, industries and agriculture. A reduction in river base flow also decreases the dilution of municipal and industrial wastes added downstream, posing pollution and health hazards.

The potential direct negative environmental impacts of the use of groundwater for irrigation arise from over-extraction (withdrawing water in excess of the recharge rate). This can result in the lowering of the water table, land subsidence, decreased water quality and saltwater intrusion in coastal areas.

Upstream land uses affect the quality of water entering the irrigation area, particularly the sediment content (for example from agriculture-induced erosion) and chemical composition (for example from agricultural and industrial pollutants). Use of river water with a large sediment load may result in canal clogging.

The potential negative environmental impacts of most large irrigation projects described more in detail below include: waterlogging and salinization of soils, increased incidence of water-borne and water-related diseases, possible negative impacts of dams and reservoirs, problems of resettlement or changes in the lifestyle of local populations.

Waterlogging and salinization

About 2 to 3 million ha are going out of production worldwide each year due to salinity problems. On irrigated land salinization is the major cause of land being lost to production and is one of the most prolific adverse environmental impacts associated with irrigation. However, very limited research has yet been conducted to quantify the economic impact of irrigation induced salinization. Quantitative measurements have generally been limited to the amount of land affected or abandoned. Estimates of the area affected have ranged from 10 to 48% of worldwide total irrigated area. Especially the arid and semi-arid areas have extensive salinity problems.

Waterlogging and salinization of soils are common problems associated with surface irrigation. Waterlogging results primarily from inadequate drainage and over-irrigation and, to a lesser extent, from seepage from canals and ditches. Waterlogging concentrates salts, drawn up from lower in the soil profile, in the plants' rooting zone. Alkalization, the build-up of sodium in soils, is a particularly detrimental form of salinization which is difficult to rectify.

Irrigation-induced salinity can arise as a result of the use of any irrigation water, irrigation of saline soils, and rising levels of saline groundwater combined with inadequate leaching. When surface water or groundwater containing mineral salts is used for irrigating crops, salts are carried out into the root zone. In the process of evapotranspiration, the salt is left behind in the soil, since the amount taken up by plants and removed at harvest is quite negligible. The more arid the region, the larger is the quantity of irrigation water and, consequently, the salts applied, and the smaller is the quantity of rainfall that is available to leach away the accumulating salts.

Excess salinity within the root zone reduces plant growth due to increasing energy that the plant must expend to acquire water from the soil. The tolerance of crops to salinity is variable: clover and rice are more sensitive to salts than barley and wheat. Comprehensive studies of farm-level effects of irrigation-induced salinity indicate that the yields of paddy and wheat are around 50% lower on the degraded soils and net incomes in salt-affected lands are around 85% lower than the unaffected land.

Irrigation-related salinity has adverse effects not only on the production areas, but also on areas and people downstream. The rivers, particularly in arid zones tend to become progressively more saline from their headwaters to their mouths. The aquifers interrelated with the river are highly saline and the salts discharged to the river system from saline aquifers adversely affect downstream water users, particularly irrigated agriculture and, in some special cases, wildlife.

Many of the soil-related problems could be minimised by installing adequate drainage systems. In Egypt, for example, the installation of drainage systems effectively reduced soil salinity. The average yield for wheat increased from 1 ton/ha before drainage to about 2.4 tons/ha. Similarly, the yield for maize increased from 2.4 tons/ha to 3.6 tons/ha after drainage infrastructure was completed. Drainage is a critical element of irrigation projects, that however still too often is poorly planned and managed. Waterlogging can also be reduced or minimized, in some cases, by using micro-irrigation which applies water more precisely and can more easily limit quantities to no more than the crops needs.

Water-borne and water-related diseases

Water-borne or water-related diseases are commonly associated with the introduction of irrigation. The diseases most directly linked with irrigation are malaria, bilharzia (schistosomiasis) and river blindness (onchocerciasis), whose vectors proliferate in the irrigation waters. Other irrigation-related health risks include those associated with increased use of agrochemicals, deterioration of water quality, and increased population pressure in the area. The reuse of wastewater for irrigation has the potential, depending on the extent of treatment, of transmitting communicable diseases. The population groups at risk include agricultural workers, consumers of crops and meat from the wastewater-irrigated fields, and people living nearby. Sprinkler irrigation poses an additional risk through the potential dispersal of pathogens through the air.

The risk that one or more of the above diseases is introduced or has an increased impact is most likely in irrigation schemes where [8]:

- soil drainage is poor, drainage canals are either absent, badly designed and/or maintained;
- rice or sugar cane is cultivated;
- night storage reservoirs are constructed;
- borrow pits are left with stagnant water;
- canals are unlined and have unchecked vegetation growth.

The impact of dams on flooding

The function of dams and reservoirs in flood control is to reduce the peak flows entering a flood prone area. Rather than maintaining high water levels for increased head or sustained water supply for irrigation, flood control operation requires that water levels be kept drawn down deliberately prior to and during the flood season in order to maintain the capacity to store any incoming floodwater. However, flood plains may be productive environments because flooding makes them so. Flooding recharges soil moisture and replenishes the rich alluvial soils with flood deposits of silt. In arid areas flooding may be the only source of natural irrigation and soil enrichment. Reduction or elimination of flooding has the potential for impoverishing flood recession cropping, groundwater recharge, natural vegetation, wildlife and livestock population in the flood plain which are adapted to the natural flood cycles.

To maintain the productivity level of the natural systems, compensatory measures have to be taken, such as fertilization or irrigation of agricultural lands. In addition, when channelization measures reduce the frequency of flooding, the sediments entering the river systems from catchment areas upstream will be passed to the mouth of the river unless overflow areas are present downstream. Channel modification can result in a number of negative environmental impacts. Any measure that increases the velocity of flow increases the erosive capacity of the water. Although channel improvement can alleviate flooding problems in the treatment area, flood peaks are likely to increase downstream, thus simply transferring the problem elsewhere. Dikes built on the flood plain to exclude water from certain areas affect the hydrology of the area, and can have impacts on wildlife and livestock habitat and movement.

The impact of dams on fisheries and wildlife

Fishery alongside the rivers usually declines due to changes in river flow, deterioration of water quality, water temperature changes, loss of spawning grounds and barriers to fish migration. A reservoir fishery, sometimes snore productive than the previous fishery alongside the river, however, is created.

In rivers with biologically productive estuaries, both marine and estuarine fish and shellfish suffer from changes in water flow and quality. Changes in freshwater flows and thus the salinity balance in an estuary will alter species distribution and breeding patterns of fish. Changes in nutrient levels and a decrease in the quality of the river water can also have profound impacts on the productivity of an estuary. These changes can also have major effects on marine species which feed or spend part of their life cycle in the estuary, or are influenced by water quality changes in the coastal areas.

The greatest impact on wildlife will come from loss of habitat resulting from reservoir filling and land use changes in the catchment area. Migratory patterns of wildlife may be disrupted by the reservoir and associated developments. Aquatic fauna, including waterfowl, amphibians and reptiles can increase because of the reservoir.

Socio-economic impacts irrigation schemes

The objective of irrigation projects is to increase agricultural production and consequently to improve the economic and social well-being of the rural population. However, changing land use patterns may have other impacts on social and economic structure of the project area. Small plots, communal land use rights, and conflicting traditional and legal land rights all create difficulties when land is converted to irrigated agriculture. Land tenure/ownership patterns are almost certain to be disrupted by major rehabilitation works as well as a new irrigation project. Similar problems arise as a result of changes to rights to water. Increased inequity in opportunity often results from changing land use or water use patterns. For example, owners benefit in a greater proportion than tenants or those with communal rights to land. Access improvements and changes to the infrastructure are likely to require some field layout changes and a loss of some cultivated land.

Irrigation projects tend to encourage population densities to increase, either because of the increased production of the area or because they are part of a resettlement project. Impacts resulting from changes to the demographic/ethnic composition may be important and have to be considered at the project planning stage through, for example, sufficient infrastructure provision.

The most significant issue arising from large dam construction is resettlement of people displaced by the flooding of land and homes. This can be particularly disruptive to communities and insensitive project development would cause unnecessary problems by lack of inadequate compensation of the affected population. Human migration and displacement are commensurate with a breakdown in community infrastructure which results in a degree of social unrest and may contribute to malnutrition. As an example of the number of people displaced by the construction of a dam, filling of the reservoir behind the High Aswan Dam displaced 50000 to 60000 people in Egypt and some 53000 people in the Sudanese portion.

Changing land patterns and work loads resulting from the introduction or formalizing of irrigation are likely to affect men and women, ethnic groups and social classes unequally. Groups that use common land to make their living or fulfill their household duties, for example for charcoal making, hunting, grazing, collecting fuel wood, growing vegetables, etc. may be disadvantaged if that same land is taken over for irrigated agriculture or for building irrigation infrastructure. Women, migrants groups and poorer social classes have often lost access to resources and gained increased work loads. Conversely, the increased income and improved nutrition from irrigated agriculture may benefit women and children in particular.

The most common socio-economic problems reducing the income generating capacity of irrigation schemes are:

- The social organization of irrigation operation and maintenance (O&M). Poor O&M contributes significantly to long-term salinity and waterlogging problems and needs to be adequately planned at the design stage to sustain the long-term development of the schemes.
- Reduced farming flexibility. Irrigation may only be viable with high-value crops, thus reducing extensive activities such as grazing animals, operating woodlots, etc.
- Changing labour patterns that make labour-intensive irrigation unattractive.
- Insufficient external supports such as markets, agrochemical inputs, extension and credit facilities.

User participation at the planning and design stages of both new schemes and the rehabilitation of existing schemes, as well as the provision of extension, marketing and credit services, can minimize negative impacts and maximize positive ones.

Alternatives to mitigate the negative impacts of irrigation projects

Alternatives exist to mitigate adverse effects of irrigation development. Some of them are listed below:

- locating the irrigation project on the site where negative impacts are minimized;
- improving the efficiency of existing projects and restoring degraded croplands to use rather than establishing a new irrigation project;
- developing small-scale, individually-owned irrigation systems as an alternative to large-scale, publicly-owned and managed schemes;
- using sprinkler irrigation and micro-irrigation systems to decrease the risk of waterlogging, erosion and inefficient water use;
- using treated wastewater, where appropriate, to make more water available to other users;
- maintaining flood flows downstream of the dams to ensure that an adequate area is flooded each year, among other reasons, for fishery activities.

Conclusion

The many disappointing results, irrigation can be a central component in producing food for the world’s growing population and in sustaining the livelihood of farmers. In the past many positive examples have been created. It is therefore vital that engineers and economists rehabilitate the reputation of irrigation by embarking on more effective irrigation projects - projects in which the give due attention to long-term social and environmental impacts. Such an attitude requires a change in the current investment appraisal rules that make use of the notion “net present value”, by which future costs and benefits are reduced by a discounting procedure. It can be argued that such discounting is only valid if the next generation is expected to be wealthier than the present and if the natural resources are yet unlimited. Otherwise, the economic practice of regarding present income as being worth much more than future income leads to an over-exploitation of natural resources at the expense of later generations.

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