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DEALING WITH THE INTER-DISCIPLINARITY OF CLIMATE CHANGE, FOOD SECURITY AND ENERGY ALTERNATIVES: SOME INDIAN INITIATIVES

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Abstract: *In association with the impact on forests, the major impacts of climate change in India would be on the land-surface and ground water hydrology and the agricultural food-production. The critical ecological challenge in future will be whether the available natural resources are sufficiently available to support food production as well as to generate ecosystem services. There already is a significant pressure on ecosystems because of continuously increasing population and extensive land use changes. Sustainable use of land and water resources requires that these scarce resources be appropriately allocated among various competing human activities. World-over, there is a realization now that climate change research calls for a multi-disciplinary and integrated approach. Moreover, it becomes important that at local and regional scales mechanisms of GHG- interactions with water, light, nutrients and temperature should be investigated, and the effects integrated in such a fashion as to quantify the cumulative impact of GHG- increase. This article, inter alia, focuses on the above-mentioned issues and delineates some of the activities related to the research being carried out in India. Some of the worth-mentioning recent research activities in India pertain to the quantification of environmental water demand (EWD), methane emissions from hydroelectric reservoirs, investigations into the inter-dependencies between bio-geochemical cycling and climatic perturbations, linkages between food-crisis, ecological foot-printing, ecological risk assessment and ecological economics.*

1. INTRODUCTION

The recent surge in oil prices combined with the day by day increasing commodity prices has already hit developed and developing countries hard. This has dramatically changed the import and export scenario. For instance, in Africa alone the import of coarse grains have increased nearly eight fold during 1970-2004. In 1970 the net agricultural trade had a surplus of US $3.3 billion in Africa, and it turned into a deficit of US $4.4 billion in 2004 *(www.fao.org/nr/water/docs/sirteconceptnote.pdf)*.

Combined with that, there is an acute and formidable global food-crisis. Increased climate variability with its associated impact on water resources, land, forests, and biodiversity may make it worse [1, 2]. Even small reductions in rainfall lead to considerable decrease in river water flow. The soil will also face many direct and indirect impacts of aberrations in rainfall-intensity and frequency. This may lead to soil-erosion and desertification. Consequently, the length of growing seasons as well as the area suitable for agriculture will also decrease. There will be significantly negative impacts on energy sector too. On of the safer (so-far believed) routes of energy-generation i.e. hydro-electricity needs a closer examination in this context. Perturbations in rainfall would lead to unexpected perturbations in hydroelectric potential, variations in run-off patterns, unexpected siltation problems etc.

In view of the recent research activities in the area of environmental water demand [3, 4], methane emissions from hydroelectric reservoirs [5], inherent inter-connections between bio-geochemical cycling and climatic perturbations [6], the present paper discusses various linkages between food-crisis, ecological foot-printing, ecological risk assessment and ecological economics.

2.. ENERGY AND WATER

Energy production, consumption and distribution has several environmental repercussions at the local, regional and global levels. Energy and water sectors are very strongly inter-linked and both are integral requirements of the food-sector. Hence, there should

be an integrated management of water so as to serve the needs of energy and agriculture both, sectors which are dependent on it. Ultimately, it demands an integrated management of air, water and land resources. Therefore, one needs to comprehensively understand various local, regional and global (ecological) linkages between air, water and land environments [7].

3. BIO-FUELS AND FOOD PRICES

In order to combat energy crisis, many countries have adopted the strategy of looking for alternative energy sources like bio-fuels etc. However, bio-fuels have their own environmental and economic implications. Since they promote monoculture, they have an adverse impact on agricultural productivity–and thus a negative impact on food-prices. Moreover, if the full emissions costs (like in refining and transporting) of producing the bio-fuels are taken into account, almost all the bio-fuels used today will cause more green house gas-emissions than conventional fuels. Corn-based ethanol almost doubles GHG-emissions over 30 years mainly as a result of land use changes. Cellulosic ethanol made in the US from switch-grass produces 50% more emissions than gasoline does *(seattletimes.nwsource.com/html/nationworld/2004171188_ethanol08.html).*

4. HYDROELECTRICITY AND AGRICULTURE

The food crisis trap that threatens the globe is due not only to the lack of investment in the agricultural sector, but also to its vulnerability to climate changes reflected mainly through the undesirable perturbations in the frequency and amplitude of rainfall. Asian farming depends to a large extent on rainfall, which is not behaving normally for past many years. This fact increases its dependence on irrigation facilities and power (electricity) requirements-in other words, on hydroelectricity dams. However, recently hydroelectricity dams have themselves come under a thick cloud of controversies related to their potential for methane emissions. This issue is again dealt with in one of the subsequent sections, where we have stressed the need for developing local, regional and global emission factors [5] for green house gases (GHGs).

In addition to that we have the problems related to environmental degradation in terms of deforestation, desertification, air, water and soil pollution. As a result there is significant loss of biodiversity and decline in water quality and quantity. According to some of the IPCC (Intergovernmental Panel on Climate Change)– estimates, climate change can result in reducing crop yields by about 50% in many countries. There is a strong link between energy and food prices. Fluctuations in energy prices are bound to almost immediately result in unexpected fluctuations in food prices.

5. IMPACT OF ACID RAIN ON AGRICULTURE AND AQUACULTURE

Acid rain is no longer just a local problem of urban areas, its impact has spread into pristine rural areas too [8]. It adversely affects both terrestrial and aquatic ecosystems [9]. In terrestrial ecosystems, these adverse impacts are generally manifested through effects like necrosis of the plant leaf, stomatal aberrations and clogging, root-decay, and the resultant decline in the vegetative productivity.

In aquatic ecosystems, these adverse effects result in the enhancement of species-mortality at different trophic levels (phytoplankton, zooplankton, and fish etc.) and are essentially the results of severe perturbations in nitrogen and phosphorus cycling, retardation in chlorophyll growth, and subsequent effects on feeding, respiration, and mortality of various higher-level species.

In view of global climatic changes and their environmental impacts, these perturbations in terrestrial and aquatic ecosystems need to be appropriately understood and quantified so as to take pragmatic environmental management decisions. This necessitates taking recourse to ecological systems analysis and ecological risk assessment. As far as ecological risk assessment (ERA) is concerned, there are only few models available in literature, which simultaneously include terrestrial as well as aquatic ecosystems for treatment and analysis. An integrated ecological risk assessment model must include the most essential physical, chemical, and biological parameters representing various physico-chemical and biological processes at air-water, air-land, and land-water interfaces. Some attempts in this direction are already being made in India [7].

6. ECOLOGICAL FOOT-PRINTING AND ECOLOGICAL ECONOMICS

Together with the environmental and ecological risks, the other significant danger that faces us today is galloping population growth combined with food and material requirements, which are growing enormously day by day and, in turn, are causing substantial problems regarding the management of air, land and water.

The sustainability of our future society is directly proportional to the rationality it adopts in the use of

natural resources. The most important need of the hour today is to evolve a sound understanding of ecology and economy, and to integrate them in such a manner as to ensure sufficient feed-back controls, which finally help ecosystems in enhancing their self-rectifying capacity. Ecological Foot-printing (EF) is one such example of integration between ecology and economics [10-13]. The basic premises on which EF is based can be summarized as follows :

- Every individual, process, activity, and region has an impact on the earth. And these impacts (due to resource use and waste-generation) can be quantified in terms of biologically productive area.
- Consumption patterns as well as waste-generation-potentials can be estimated in terms of the land-area needs for different human ecosystems.
- Estimates for biological productivity of these systems can also be worked out as ecosystems' supportive (resource-utilization) and assimilative (pollution-sink) capacities.

As far as ecological wealth of any region is concerned, it depends on two important factors : one accrues because of the ecological-goods the ecosystems in the region contain and the other one is due to the ecological-services they provide. Wetlands happen to be such important ecosystems, as provide a suitable link between terrestrial and aquatic ecosystems, and thus have a significant and sensitive ecological role especially in terms of bio-geo-chemical cycling of carbon, nitrogen, phosphorus and sulfur etc.

7. DEVELOPMENT OF LOCAL, REGIONAL AND GLOBAL GHG-EMISSION-FACTORS

Reservoirs and hydroelectric dams need a closer analysis of the impacts due to dams, both in terms of GHG-emissions and the uncertainties associated with estimation. Which emissions to count as net emissions and how to deal with the emissions of CO_2 and CH_4 when they occur at different periods are some of the pertinent issues. The net emissions are the emissions which take into account all the sources as well as sinks of GHGs in the watershed. These emissions may differ significantly from one geographical region to another and depend, inter alia, on temperature, wind speed, solar radiation, physico-chemical water quality parameters, adjacent biospheric composition and several dam operating conditions as well as the age of the reservoir. In addition, there may be diurnal, seasonal and annual variations too. Moreover, the main scientific debate at the moment is centered around the uncertainties associated with extrapolating emissions measured at selected parts and selected intervals of time.

Thus, there is a strong need for developing region-specific spatio-temporal emission-factors (functions). This will not only reduce the spatial uncertainties but also the uncertainties associated with diurnal, seasonal and annual variations. Recently, we have made some attempts in this direction. It is pertinent to mention here that development of such emission factors for GHGs is an important requirement under IPCC guidelines.

8. CONCLUSION

A vital area for technology development and interventions is land resource management or in other words an effective and pragmatic land-use planning. These technology-interventions should be aimed at more effective capture and infiltration of rainwater, recharge of groundwater, soil-moisture-retention and environmentally benign management and harvesting of run-off water for various energy-related options [14-15]. Future studies must be able to address the following:

- In view of the food-crisis looming large all over the globe and continuously rising commodity prices, there is a strong need for assessing the challenges faced by the agricultural sector and to look into the strong linkages between energy-sector and climate change.
- In order to have food-security and stability in the prices of food items one has to look into the factors like population migration from rural areas to urban areas. The trends of urbanizations have to be properly managed and appropriately oriented.

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