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Hydrological factors

B H Wilkinson

Institute of Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

The hydrological cycle interacts strongly with the biochemical cycles. Consequently, land use change such as afforestation, deforestation, desertification and urbanisation may have a major impact on hydrology at a continental, regional, river basin, or subcatchment scale. Within a river basin, this impact may lead to such effects as an increase in flood size and frequency, a reduction in river or groundwater flow which imposes a stress on water resources, a deterioration in water quality, or an increase in sediment transport, soil erosion, landslips, etc. At a continental scale, major land use changes may affect global climate and regional hydrology.

In view of the above issues, it was appropriate that one of the discussion sessions should be concerned with predicting the hydrological consequences of land use change through the use of mathematical models.

The discussions were focused on a number of questions, and a summary is presented below.

Which land use changes are of most concern to hydrologists?

Afforestation/deforestation

The importance of land use changes resulting from afforestation or deforestation of a region was fully recognised by the group. Reference was made to Law's 1960's research on the Stocks Reservoir Catchment*. From a series of lysimeter interception studies, he concluded that afforestation of the reservoired catchment would result in some 20% loss of runoff. Subsequently, more detailed work on paired grassland and forested catchments in Plynlimon (Wales) and elsewhere has confirmed these early findings. Thus, in the humid temperate regions, afforestation will generally lead to a reduction in the water supply yield from a catchment.

With respect to the impact of afforestation/ deforestation on floods, it was noted that there is a substantial body of data from the humid temperature regions of the world, which shows that deforestation reduces the time for the peak flood to arrive but increases the size of the peak. In some cases, the increase may be very dramatic. Other detrimental effects of afforestation were noted, such as the increase in sediment loads in rivers which occurs during both planting and timber extraction. There are also measurements to show that coniferous forests will scavenge pollutants from the atmosphere. The pollutants are then carried by rain to the land surface and, if the soil has little buffering capacity, acidification of surface waters may result. Because of these important impacts, there has been a major effort in the hydrological modelling of forests. The use of the Institute of Hydrology's (IH) hydrological rainfall runoff model (HYRROM) to predict the change in the water resources of a Welsh catchment due to proposed afforestation was described.

Agriculture

The impact of agricultural practice on local hydrology was discussed. The drainage of much of eastern England by mole ploughing or tile drains was noted. Such drainage may have a major effect on flood peaks and the time to peak, depending on whether the catchment soil is predominantly clayey or sandy.

Agriculture may have a marked effect on the quality of surface waters and groundwaters. The ploughing of permanent grassland in south-east England during the 1940s and 1950s, and its conversion to arable land have led to a major release of nitrate. The problem has been exacerbated by the use of nitrogen-based fertilizers. Models of both surface waters and groundwaters have been and are being developed to predict future impacts. The problem with pesticides and herbicides was largely unrecognised some 15 years ago, but the substances are now finding their way into drinking water supplies. Advanced hydrological modelling is required to gain an understanding of how such substances move through the soil and into watercourses.

Urbanisation and industrial development

The group discussed ways in which increasing urbanisation and the growth of industry impact on the natural drainage systems, as rural land is

*Summarised in Calder, I.R. 1990. *Evaporation in the uplands,* 1-2. Chichester: Wiley.

converted to a concrete or bitumen surface and watercourses are channelled and piped. Heavy polluting loads may be carried by rainwater from the urban surface into streams and rivers. In addition, there are associated sewage effluent discharges. There has been a major growth in modelling activity to address the urban problems over the last ten years.

For which land use change situations are suitable hydrological models available?

The group noted the wide range of hydrological models available. They saw the role of the model to predict surface water or groundwater flows within and from a catchment for a given effective rainfall distribution. The models vary from the relatively simple storage types where the catchment is represented by one or more cascading reservoirs to physically based distributed models, such as the systeme hydrologique Europeen (SHE) and the IH distributed model (IHDM) which require detailed representation of the spatial properties within a catchment, eg the distribution of hydraulic properties of the soils, etc.

A wide range of models also exists for predicting water quality, but these were generally a component part of a hydrological flow model. It was accepted that, if it is not possible to develop a reliable flow model for a particular situation, then any attempt to model water quality in this situation will fail.

Are there any hydrological modelling techniques which should be particularly encouraged?

The group first considered those models which use historic records of hydrological data, such as precipitation, river flow, groundwater flow, etc, to establish parameters in statistical or storage type models of catchments (eg HYRROM). Such models will predict runoff for a given rainfall input for the catchment in question, and for the prevailing land use during the period over which the hydrological data used in the parameterisation were collected. Comparison of the model parameters from catchments with the same general hydrological setting but with different land uses enables the sensitivity of the model parameters to land use changes to be identified.

The second approach is to use models which are more physically based. The catchment is usually subdivided into a number of distinct regions, often on a grid pattern, and the appropriate hydrological equations are set and solved numerically by computers. Some of the larger models may demand a major computing facility. As a precursor to running such models, understanding and quantification of the hydrological processes for a variety of land use situations are needed. These processes include interception, evaporation, transpiration, infiltration, surface water runoff, shallow subsurface runoff, deep groundwater flow, sediment transport, water quality changes, soil wate storage, etc. These processes may change during a day, with the season, and through time for a given land use. For example, the closure of the canopy during the growth of a forest may profoundly affect the hydrology within a catchment. Models of this latter type include SHE and IHDM. There was genera agreement that the models based on a physical description of the hydrological processes are likely tc be more reliable in making predictions in situations where there have been major land use changes. However, the more traditional models still have a role to play where the perturbations to the system are not too extreme. The group reached a consensus that it was healthier to have research workers moving forward with developments on a series of fronts, rather than focusing on one particular area.

Are there problem areas associated with the development of hydrological models for land change assessment?

Several problems in model development were identified. For example, there was discussion over the choice of scale for physically based hydrological models. Too coarse a grid scale may lead to the loss of the description of the spatial inhomogeneity within the catchment, while too fine a grid scale may lead to unacceptably long computer runs. It was recognised that much more computing power would be needed in the future if the hydrological impacts of land use changes over very large catchment basins are to be modelled. Such effects may arise as a result of climate change.

The availability of some data bases was causing concern, in that they were so costly that it took them out of the reach of some research groups. The possibility of digitising remotely sensed satellite data and using them in hydrological models was discussed. This was seen as opening up exciting modelling possibilities, but concern was also expressed that costs may be prohibitive.

It was accepted that geographical information systems have a key role to play in assembling and manipulating data for use in hydrological model development.

How should models be validated?

A number of the participants expressed concern over the proliferation of hydrological models. They were particularly concerned that there was no standard against which the performance of a model could be judged. While this may not pose a problem for the researcher who is able to follow new developments closely, the 'model user' may be making predictions of events tens of years into the future, with no means of assessing the reliability of such predictions. There was a plea for work to be done in establishing a data set and validation procedures against which the reliability of hydrological models could be tested. There was a tendency among model developers to claim that 'my model is better than your model', with little actual justification.

Is there the need to link hydrological and ecological (biological) models?

The group felt that more needed to be done to improve the representation of biological processes within the hydrological models. The view was also expressed that, in many situations, those working on the ecological impacts of land use change could not develop sound predictive ecological (biological) models, unless there was a reliable hydrological model available as a foundation.