Research issues in spatial land and water management, examples from the UK, Panama and South Africa.

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ABSTRACT

Land use and land use change have profound effects on water resources, not least if the land use is forestry or if it involves forest related activities. This paper describes the application of spatial land and water analysis techniques that have been, and are being, applied to address forest and water policy issues in the UK, South Africa and Panama.

In many ways the policy issues are similar in each of the countries. They relate to how we can best manage forest lands to meet competing demands, particularly as they relate to demands for production (e.g. timber and water), Conservation, Amenity and Recreation (CARE) products or for supporting peoples livelihoods.

It is argued that with the help of these techniques we may be able to work towards developing land-use and water management policies that make use of our best science, that are not only upwardly and downwardly compatible, from the local rural watershed scale to the global scale, but are also consistent with other global and local policies relating to sustainability, climate change, biodiversity, trade, food production and poverty alleviation.

Commercial forestry has often been promoted by development organisations because of its perceived environmental benefits. Yet science based research has shown that many of the expected environmental benefits (which may in some cases be provided by natural forests) cannot be achieved through commercial plantations. Increasingly we are now becoming aware of the environmental dangers, rather than benefits that have been caused by these plantations. Not only is there usually a high cost in terms of lost water associated with fast growing commercial plantations but, as has been recognised by the government of South Africa, there may also be dangers associated with “escaping” plantation trees. The South African Government has found it necessary to fund a billion Rand “Working for Water Programme” for the purposes of controlling and eradicating alien invading tree species.

The developments in the UK, South Africa and Panama indicate that slowly a “Blue Revolution” is taking place in the way we manage land use and water resources and in which science is becoming better connected to policy. Major challenges still remain before this revolution can be completed. How can we match resource based development objectives with more people focussed, poverty alleviation objectives? When we look towards forests for their carbon sequestration benefits in preventing further global warming should we not also be considering these benefits in relation to more local water resource disbenefits? It is argued that these are some of the questions that still need to be resolved.

LOWLAND FORESTS AND WATER RESOURCES IN THE UK

The UK Government's 1995 White Paper on Rural England included a proposal, mainly on conservation and amenity grounds, to double the area of woodland cover within England by the year 2045. This proposal was made at the same time that the UK was experiencing the driest and warmest summer on record, conditions that led to widespread water supply shortages and costly drought relief operations in some regions. Climate change scenarios suggest that such droughts could become much more frequent over the next 50-100 years. Questions were later raised (House of Commons Environment Committee, 1996) concerning the possible impacts on UK water resources and the water environment of the combined effects of climate change and such a large expansion in woodland.

At that time it was difficult to predict accurately the water quantity impacts of UK lowland afforestation (Calder *et al*., 1997; Calder, 1999), even under the present climate, for two main reasons:

1. In the lowlands of the UK, water use by transpiration generally exceeds that by interception. Tree physiology exerts a strong control over transpiration rates, depending on interactions between atmospheric demand and available soil water. Since this can result in lower or higher transpiration losses when compared with shorter crops, predicting evaporation differences, even under present climatic conditions, becomes very uncertain.

2. Prior to the execution of current studies information on the evaporative losses for different tree species growing on contrasting soil types in lowland Britain was limited or non-existent. Virtually no information was available on the evaporative characteristics of woodland growing on drought-prone soils overlying sandstone geology or, for that matter, on derelict soils, yet it was expected that much of the new planting would take place in the Midlands of England on just these soil types. Consequently, it is was not possible to determine the direction of the impact let alone the magnitude.

Recognising these difficulties, the Department of the Environment, Transport and the Regions (DETR) commissioned a scoping study to investigate the possible range of water resource impacts associated with woodland on chalk and sandstone. A part of this study, which is reviewed here, involved running the HYLUC97, GIS based evaporation model, with trial model parameters derived from earlier work (Calder *et al.,* 1997, 1999), at the Greenwood Community Forest site in the Midlands of the UK .

"SCOPING STUDY"APPLICATION OF THE HYLUC MODEL TO INVESTIGATE THE RANGE OF HYDROLOGICAL IMPACTS OF WOODLAND EXPANSION WITHIN THE GREENWOOD COMMUNITY FOREST IN THE ENGLISH MIDLANDS

To investigate the range of possible impacts resulting from broadleaf woodland expansion in the Greenwood Community Forest, the HYLUC model was applied using parameter values derived from earlier modelling study and field studies over chalk, but amended to take into account expected differences in soil water availability expected on the sand and clay-loam soils of the Midlands. A full description of the HYLUC model and its development is provided by Calder (2001).

The study site was the Greenwood Community Forest in Nottinghamshire. Nottinghamshire County Council supplied information on land use, soil type and geology as GIS files (Figure 1). Application of the HYLUC model then allowed the calculation of the range of impacts (Calder *et al.,* 1997, 1999).

The model predictions of seasonal evaporation are shown in Figure 2. These indicate that, in the long term, annual evaporation from broadleaf woodland on sand soil is 93 mm higher than that from grassland and, therefore, afforestation would reduce the average recharge plus runoff by 51%. For broadleaf woodland expansion on clay-loam soil, the predicted reduction in recharge plus runoff would be 62%. The calculated cumulative recharge plus runoff from the Greenwood Community Forest is shown in Figure 3 assuming the present forest cover. Also shown is the calculated cumulative recharge plus runoff for the proposed three fold increase in woodland cover, assuming that the increase is in proportion to the present distribution of forestry on the different soil types. Over the 24 year period from 1969 to 1993, the calculated average annual reduction in recharge plus runoff resulting from a three fold increase in woodland cover within the Greenwood Community Forest from 9% to 27%, would be 14 mm (11%).

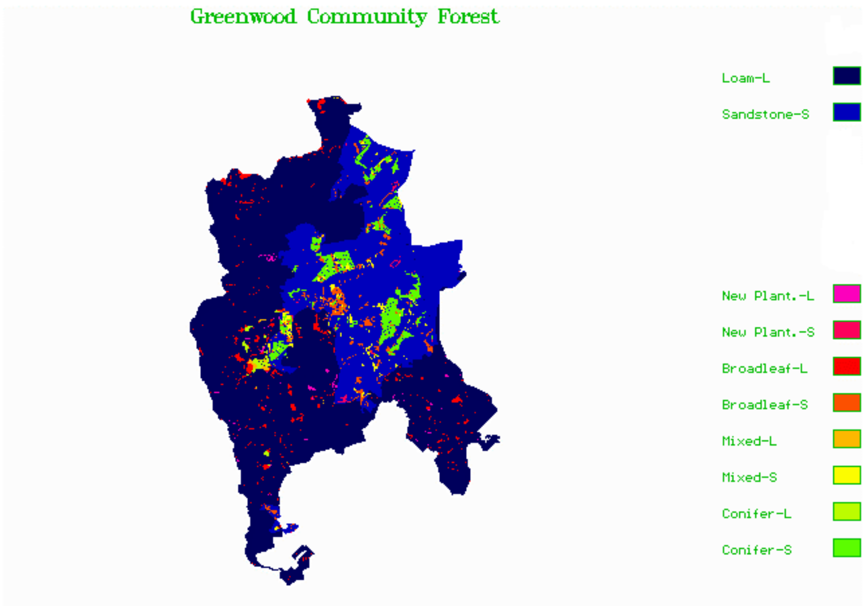


Figure 1 Forest covers within the Greenwood Community Forest. The light blue area represents the sandstone aquifer overlain by sandy soils, while the rest of the area is classified as clay-loam.

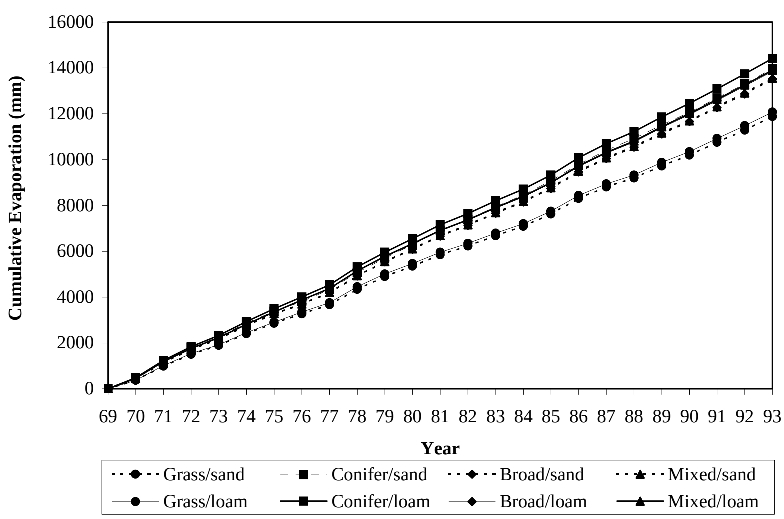


Figure 2 Predicted cumulative evaporation for different land uses within the Greenwood Community Forest. Average annual evaporation: Grass/sand, 460; Conifer/sand, 571; Broadleaf/sand, 553; Mixed/sand, 554; Grass/loam, 486;Conifer/loam, 603; Broadleaf/loam, 594; Mixed/loam, 594 mm. Average annual rain: 628 mm.

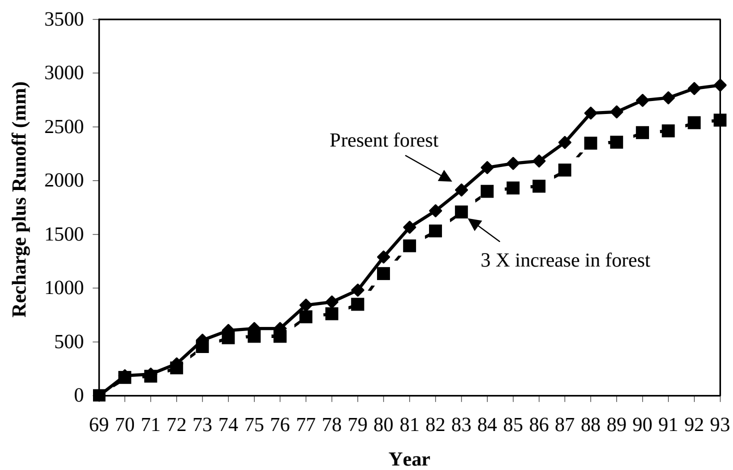


Figure 3 Calculated recharge plus runoff for the whole Greenwood Community Forest for the period 1969-1993 with the existing forest cover and with a threefold increase in forest cover.

Field studies, initiated in February 1998, are currently being undertaken at the Clipstone Forest in the Midlands of the UK to test and refine these model predictions. Preliminary results from these studies indicate that the scoping study predictions of evaporation and recharge for broadleaf forest was broadly correct. For pine forest it appears now that the scoping study predictions were underestimating the impacts on recharge of afforestation with this forest type by predicting recharge rates 46% greater than is now believed to be the case. The field studies are now indicating annual recharge rates of only 25 mm per annum, approximately a fifth of that expected under grass vegetation.

Further expansion of lowland forest in the UK for conservation and amenity purposes needs to be considered in relation to the very significant impacts on water resources that this will entail.

CATCHMENT MANAGEMENT AND POVERTY ALLEVIATION (CAMP)

The government of South Africa has recognised that not only is there usually a high cost in terms of lost water associated with fast growing commercial plantations but that there may also be dangers associated with “escaping” plantation trees. The South African Government, in the February 2000 budget, awarded a further R1,000,000,000 (over five years) to the Working for Water Programme (DWAF, 1996) for the purposes of controlling and eradicating alien invading tree species. The expectation is that without this programme the invaders would eliminate indigenous plant species and seriously reduce water resources. The programme also has, through specifically targeting the poorest in society for employment, a major poverty alleviation component.

The Programme highlights a number of issues relating to forest and water management, issues that are probably not specific to South Africa. These include how to devise and implement forest and water policy instruments which will meet the requirements of Integrated Water Resources Management (water resource, basin economics and conservation) whilst also meeting the demands of major international and donor organisations (e.g. World Bank and DFID) that policies should have an equity dimension and support and enhance (particularly the poorest) peoples livelihoods. Clearly these questions also have a spatial dimension, not least because it will be necessary to prioritise areas within a catchment to achieve maximum benefits. These questions will be addressed within the CAtchment Management and Poverty alleviation (CAMP) project that is supported by DFID in South Africa, Tanzania and Grenada. The focus of the study will be the Luvuvhu catchment in the Northern Province of South Africa, Figure 4.

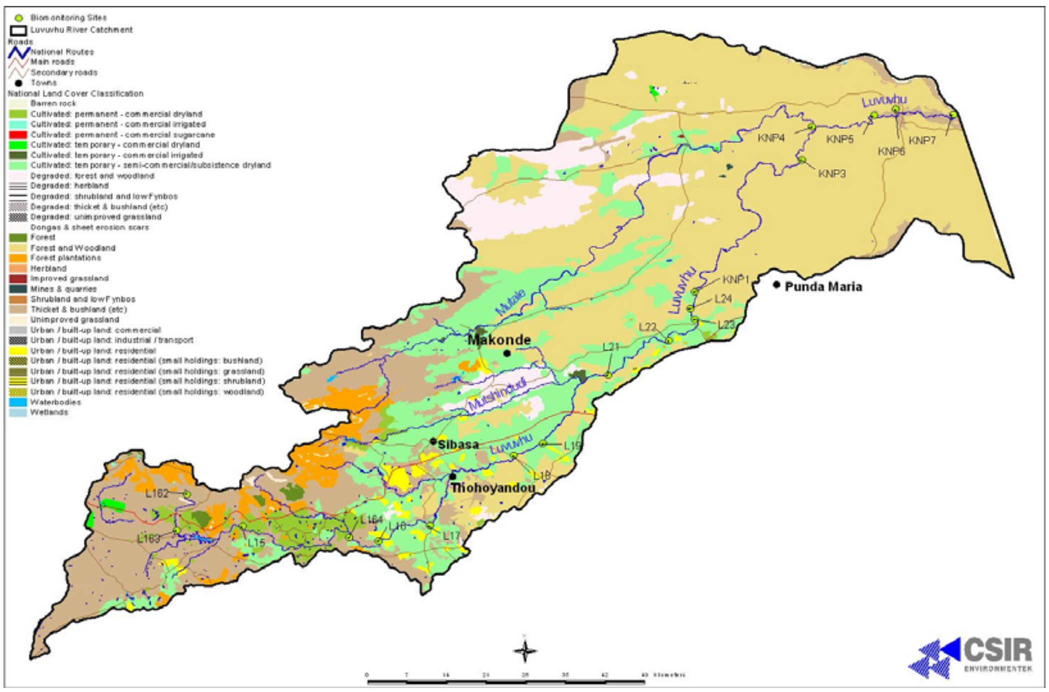


Figure 4 Luvuvhu catchment land use.

The Luvuvhu catchment demonstrates the acute problems posed for water and land use management related to forestry activities. There is potential for a considerable increase in the area of commercial forestry, it is presently affected by alien invader tree species, it is water short and it has high levels of poverty.

Spatial analysis and modelling techniques will be developed to investigate the impacts of alternative forest and water policy instruments.

> *In the opinion of the Department of Water Affairs and Forestry "by cutting down invading alien plants (such as wattles and pines), we significantly enhance the availability of water. Invasive alien plants grow and spread. If we fail to eradicate them, they will strangle our water supplies. In essence, either we pay now, or we pay more later".*

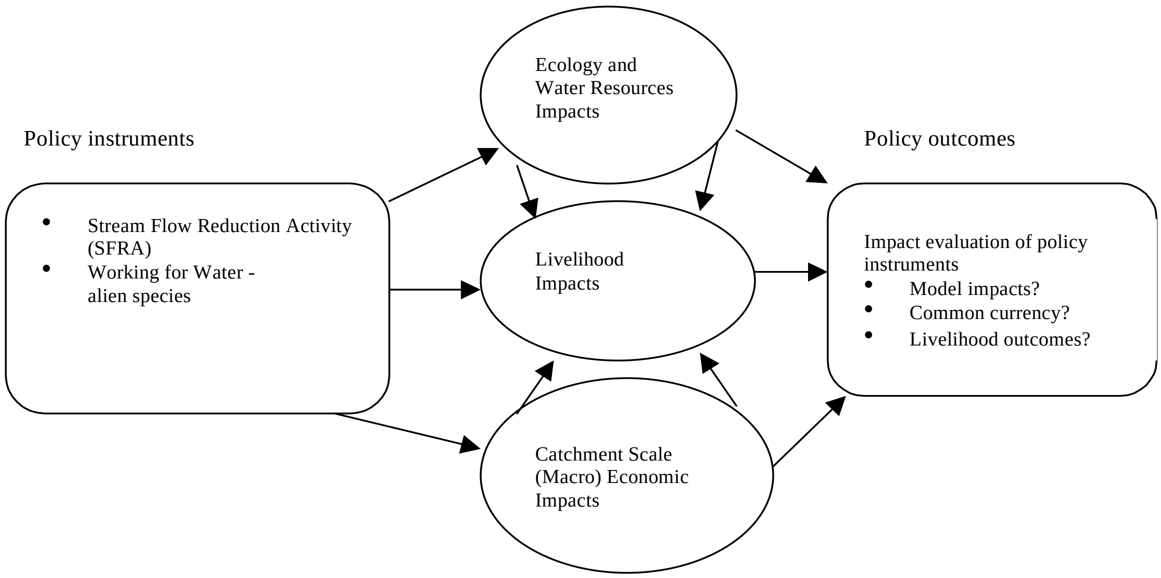


Figure 5 The CAMP project will investigate how two forest and water related policy instruments, the Working for Water Programme and the charging of landowners for Stream Flow Reduction Activities (SFRAs), will affect water resources, catchment scale ecoomics and livelihoods.

The CAMP project will focus specifically on two forest and water related policy instruments which are currently being applied in South Africa, the Working for Water Programme and the charging of landowners for Stream Flow Reduction Activities (SFRAs). Commercial forestry and sugar cane are recognised as SFRAs. The CAMP project will attempt to model the impact of these two policy instruments within the Luvuvhu catchment as they affect not only water resources and catchment scale economics but also the livelihoods of the poorest in society.

FORESTS, WATER AND THE PANAMA CANAL

.Figure 6 The Bridge of the Americas crossing the Panama Canal

The continued functioning of the Panama Canal is a central concern of the Government of Panama. The ownership of the Panama Canal was transferred from the government of the USA to the Government of Panama at the beginning of the new Millennium. During the period leading up to the change of ownership major changes were also taking place in relation to the institutional understanding of land use and water resource issues which are now leading to a reconsideration of government policies with respect to the management of the canal watershed.

With USAID support a Regional Plan (Intercarib/Nathan Associates 1996) had been produced earlier which advocated a large-scale reforestation (104,000 ha) of the lands in the Panama Canal Watershed which were under agricultural, primarily livestock production, use. The report was based on the perceived wisdom that the reforestation programme would have a positive impact on water quality and quantity and erosion, and necessarily increase annual and dry season flows. The proposals in the report were enshrined in a Panamanian Law, Law 21, in 1997. The Government of Panama later requested the World Bank to assist them in designing a project that would assist them in carrying out their responsibilities in the watershed under Law 21.

As part of the preparatory phase of the project design the World Bank commissioned various consultancies and scoping studies to investigate the current land use in the catchment, the hydrological impacts of the proposed land use change and the basin-wide economic implications of such a change.

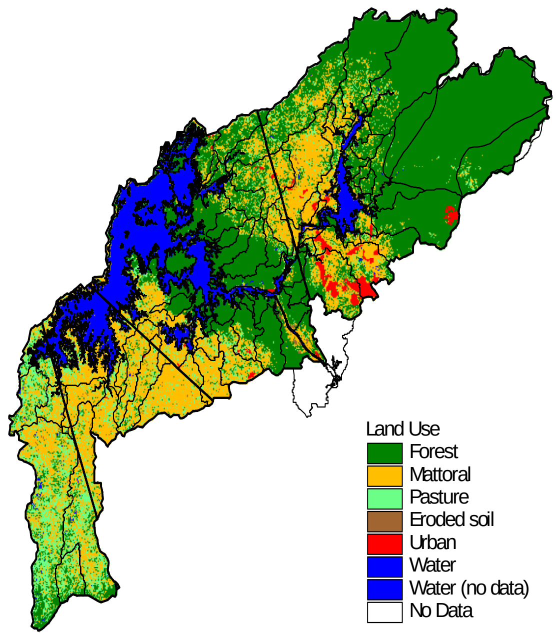
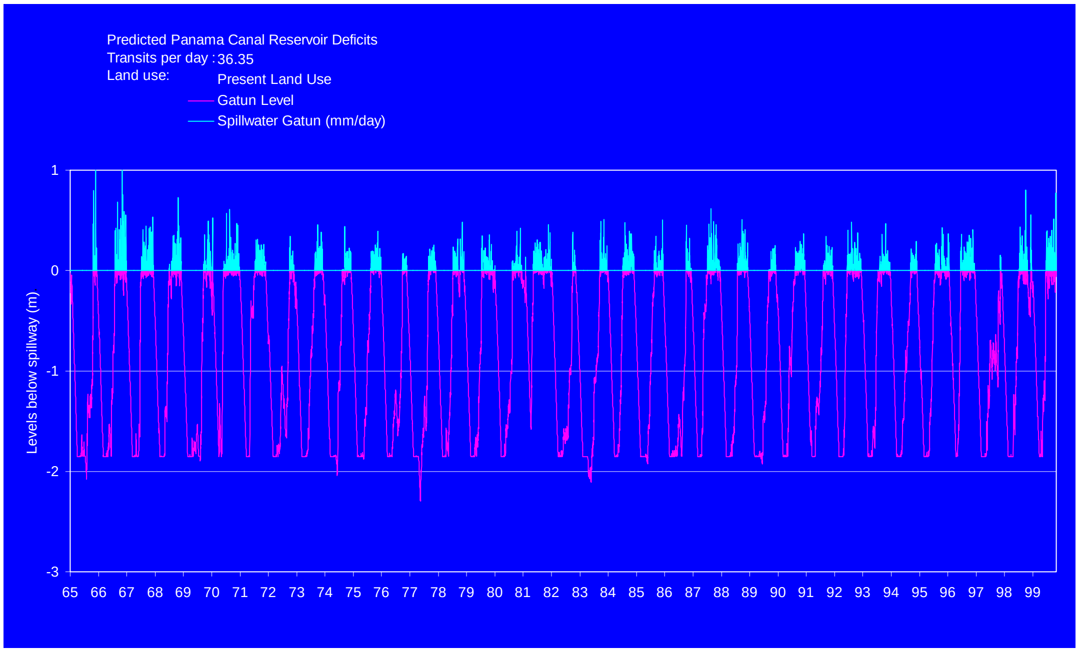


Figure 7 Existing land use in the Panama Canal Watershed

The Centre for Land Use and Water Resources Research at Newcastle University carried out the scooping study into the hydrological impacts of the proposed land use change using the HYLUC spatially distributed evaporation model using local information on land use, Figure 7. Using previously published "default" forest and non forest parameter values this model was shown to be able to describe the recorded flow regime under both three of the major subcatchments of the Panama Canal Watershed and three of the experimental catchments operated by the Smithsonian Tropical Research Institute, within an error which was essentially commensurate with the experimental error of the observations. This model was then linked to a reservoir operations model to investigate how the operation of the canal would be affected under different scenarios of land use and demand, where demand was expressed in terms of number of ship transits per day that the reservoirs could support, Figure 8.



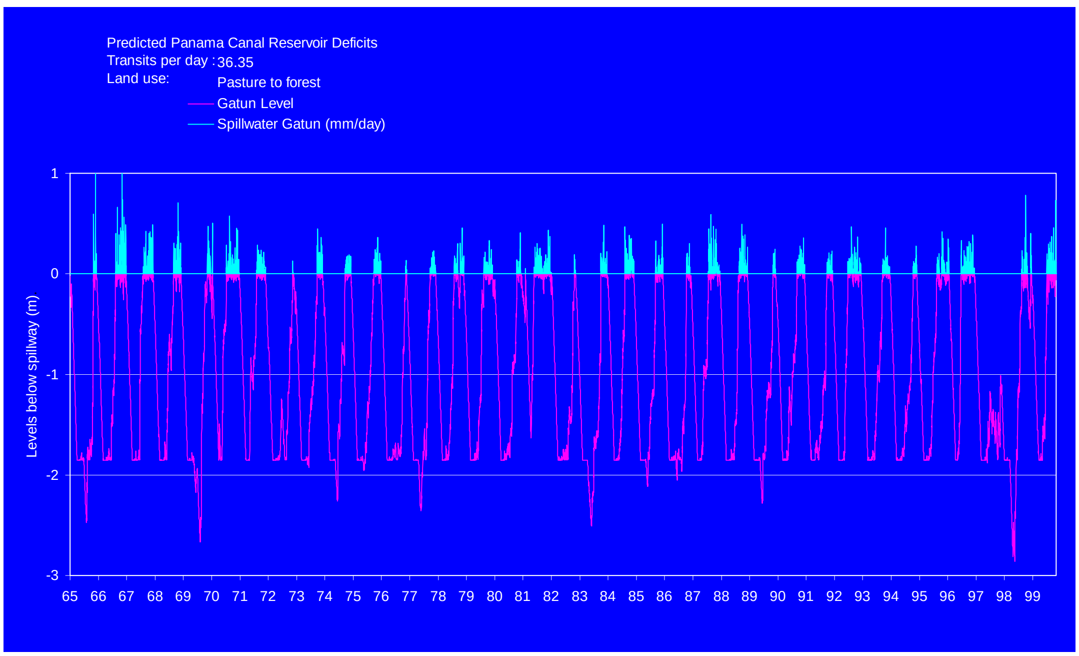


Figure 8 Predicted levels of the Gatun Reservoir feeding the Panama Canal under a present land use scenario and an afforestation (Law 21) scenario. Reservoir levels which drop below 2m are indicative of a "failure" situation when large ships would not be able to transit the Canal.

Rather than supporting the conventional wisdom that afforestation would increase flows to the canal reservoirs which would enhance the capacity of the canal the model predicts that flows would be reduced and that if the probability of a "failure" situation was kept as at present the number of transits allowed per day would also have to be reduced by about 10%. Furthermore, expected benefits of an afforestation programme in terms of erosion control are also unlikely to be achieved. To date virtually all of the commercial planting within the watershed is with teak and herbicides are generally applied to reduce competition from understorey weeds. As noted earlier, this is a situation which may lead to very much increased rates of soil erosion as compared with the generally pastoral land use that it would usually replace.

THE NEED FOR CONSISTENT POLICIES

Clearly there is a pressing need for land-use and water management policies that are based on our best science rather than myth, that are not only upwardly and downwardly compatible, from the local rural watershed scale to the global scale, but are also consistent with other global and local policies relating to sustainability, climate change, biodiversity, trade, food production and poverty alleviation. Spatial land and water technologies based on GIS systems can assist us with this task and in identifying and prioritising management options.

Commercial forestry has often been promoted by development organisations on its perceived environmental benefits. Yet science based research has shown that many of the expected environmental benefits (which may in some cases be provided by natural forests) cannot be achieved through commercial plantations. Increasingly we are now becoming aware of the environmental dangers, rather than benefits, that have been caused by these plantations. Not only is there usually a high cost in terms of lost water associated with fast growing commercial plantations but, as has been recognised by the government of South Africa, there may also be dangers associated with "escaping" plantation trees. The South African Government has had to fund a Billion Rand "Working for Water Programme" (DWAF, 1996) for the purposes of controlling and eradicating alien invading tree species.

Although the alien invader issue has been recognised in RSA, the extent of this problem has not really been quantified for the rest of the developed and developing world. The extent to which development organisations through the promotion of past and present forestry policies may have been responsible for introducing and aggravating this problem - and are now morally responsible for helping with its resolution, is perhaps another question that needs to be broached.

The developments in the UK , South Africa and Panama indicate that slowly a "Blue Revolution" is taking place in the way we manage land use and water resources and in which science is becoming connected better to policy. Major challenges still remain before this revolution can be completed. How can we match resource based development objectives with more people focused, poverty alleviation objectives? When we look towards forests for their carbon sequestration benefits in preventing further global warming should we not also be considering these benefits in relation to more local water resource disbenefits? These are some of the questions that still need to be resolved.

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