Forests and water – closing the gap between public and science perceptions

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Abstract The public perception that forests are, in all circumstances, necessarily good for the water environment, that they increase rainfall, increase runoff, regulate flows, reduce erosion, reduce floods, "sterilize" water supplies and improve water quality, has long been questioned by the scientific community. The evolving "modern" science perception suggests a more complex and generally less advantageous view of forests. It is suggested that the disparity between the two perceptions needs to be addressed before we are in a position to devise and develop land and water policies which are aimed at either improving the water environment, and by doing so improving the livelihoods of poor people by greater access to water, or conserving and protecting forests. Examples are given of "interactive" research projects in different parts of the world including the UK, South Africa, Panama and India where, through the involvement of stakeholder groups, often with representatives comprising both the science and public perceptions, research programmes have been designed and are being implemented, not only to derive new research findings with regard to the biophysical processes, but also to achieve better "ownership" and acceptance of these research findings by the stakeholder groups.

Keywords Forests; land and water related policies; perceptions; water environment

Introduction

In many countries of the world forest and afforestation programmes are still being promoted within watershed development programmes on the basis of their "hydrological services" and "headwater conservation functions". In turn the expectation is often that the increased "hydrological services" will benefit the livelihoods of poor people through increased access to water supplies.

But the public perception, that forests are, in all circumstances, necessarily good for the water environment has long been questioned by the scientific community. The relationships between forests and water have been debated since the nineteenth century (Saberwal, 1997), but to appreciate the evolving "modern" science perception the reader is referred to reviews by Bosch and Hewlett (1982), Hamilton and King (1983), Hamilton (1987), Bruijnzeel (1990) and Calder (1992), particularly as regards tropical forests, and the more recent reviews, in the light of new studies, by Calder (1999, 2000) and Bruijnzeel (2003).

It is suggested that the disparity between the two perceptions needs to be addressed before we are in a position to devise and develop evidence-based land and water policies.

In a world where increasing demands are being made on water resources for food production, for domestic consumption, for industrial use and for ecological purposes, there is a greater awareness that the costs of the generally higher water use of forests, as compared with other vegetation types, needs to be evaluated in relation to their benefits for timber and conservation, amenity recreation and environment (CARE) products and for supporting livelihoods.

Organisations which are developing land and water policies need to be aware of the disparity between the traditional public perception and the science perception of the role of forests in relation to water and it is argued that there is an urgent need to move towards a
reconciliation of these different views if we are to develop sustainable and defensible land and water policies which avoid the possibility of perverse outcomes.

This paper aims to:
• review and contrast the science and public perception of the role of forests in relation to water and identify areas where our science understanding remains weak and where further biophysical research is required;
• provide examples of ongoing research programmes, focussed in the UK, South Africa, Panama and India, which are seeking to understand the biophysical and socio-economic impacts of forests as they affect the water environment, and the land and water “perceptions” and policy processes operating in these different countries;
• outline priority areas of research for the future based on research outcomes derived so far.

The science perception and future research needs
Two of the many “myths” or “conventional wisdoms” relating to forestry and water (see Calder, 1998, 1999) are reviewed here as a means of investigating the disparity between the “science” and “public” perceptions and to identify the remaining gaps in our knowledge.

Forests increase runoff?
A new understanding has been gained in recent years of evaporation from forests in dry and wet conditions based on process studies. These studies, and the vast majority of the world’s catchment experiments, indicate decreased runoff from areas under forests as compared with areas under shorter crops. They indicate that in wet conditions interception losses will be higher from forests than shorter crops primarily because of increased atmospheric transport of water vapour from their aerodynamically rough surfaces. In dry (drought) conditions the studies show that transpiration from forests is likely to be greater because of the generally increased rooting depth of trees as compared with shorter crops and their consequent greater access to soil water.

The new understanding indicates that in both very wet and very dry climates, evaporation from forests is likely to be higher than that from shorter crops. Consequently runoff will be decreased from forested areas, contrary to the widely accepted folklore. The few exceptions, (lending some support to the folklore), are:
• cloud forests where cloud-water deposition may exceed interception losses;
• very old forests; Langford (1976) showed that following a bushfire in very old (200 years) mountain ash, Eucalyptus regnans, forest covering 48% of the Maroondah catchment, one of the water supply catchments for Melbourne in Australia, runoff was reduced by 24%. The reason for this reduction in flow has been attributed to the increased evaporation from the vigorous regrowth forest that had a much higher leaf area index than the former very old ash forest.

Conclusion. Notwithstanding the exceptions outlined above catchment experiments generally indicate reduced runoff from forested areas as compared with those under shorter vegetation (Bosch and Hewlett, 1982).

Caveat. Information on the evaporative characteristics of different tree species/soil type combinations are still required if evaporation estimates with an uncertainty of less than 30% are required. In both temperate and tropical climates evaporative differences between species and soil types are expected to vary by about this amount.
Forests regulate flows – increase dry season flows?

Although it is possible, with only a few exceptions, to draw general conclusions with respect to the impacts of forests on annual flow, the same cannot be claimed for the impacts of forests on the seasonal flow regime. Different, site specific, often competing processes may be operating and the direction, let alone the magnitude of the impact, may be difficult to predict for a particular site.

From theoretical considerations it would be expected that:

• increased transpiration and increased dry period transpiration will increase soil moisture deficits and reduce dry season flows;

• increased infiltration under (natural) forest will lead to higher soil water recharge and increased dry season flows;

• for cloud forests increased cloud-water deposition may augment dry season flows.

There are also observations (Robinson et al., 1997) which indicate that for the uplands of the UK drainage activities associated with plantation forestry increase dry season flows both through the initial dewatering and in the longer term through alterations to the hydraulics of the drainage system.

Observations from South Africa indicate that increased dry period transpiration reduces low flows. Bosch (1979) has demonstrated, from catchment studies at Cathedral Peak in Natal, that pine afforestation of former grassland not only reduces annual streamflow by 440 mm but also reduces the dry season flow by 15 mm. Van Lill and colleagues (1980), reporting studies at Mokobulaan in the Transvaal, showed that afforestation of grassland with *Eucalyptus grandis* reduced annual flows by 300–380 mm, with 200–260 mm of the reduction occurring during the wet summer season. More recently Scott and Smith (1997), analysing results from five of the South African catchment studies, concluded that percentage reductions in low (dry season) flow as a result of afforestation were actually greater than the reduction in annual flow. Scott and Lesch (1997) also report that on the Mokobulaan research catchments under *Eucalyptus grandis* the streamflow completely dried up by the ninth year after planting. The eucalypts were clearfelled at age 16 years but perennial streamflow did not return for another five years. They attribute this large lag time as being due to very deep soil moisture deficits generated by the eucalypts which require many years of rainfall before field capacity conditions can be established and recharge of the groundwater aquifer and perennial flows can take place.

Studies in India draw similar conclusions. Sikka and colleagues (Sikka et al., 2003) investigated the impacts on both flood flows and low flows of converting natural grassland to eucalypt plantation in the Nilgiris region of south India. The detailed and long term (1968–1992) paired catchment experiments in the Nilgiris, where the responses from a “control” catchment under natural grassland were compared with those from a catchment with 59% eucalypt cover, which were monitored over a period encompassing two rotations of the eucalypt crop indicate very significant reductions in low flows during the dry season. Expressed in terms of a “Low Flow Index” (defined as the 10 days average flow which is exceeded for 95% of the time of the flow record) the low flows were reduced by approximately one half during the first rotation and by one quarter during the second rotation of the eucalypt crop.

Bruijnzeel (1990) discusses the impacts of tropical forests on dry season flows and concludes that the infiltration properties of the forest are critical in how the available water is partitioned between runoff and recharge (leading to increased dry season flows).

Conclusions. Competing processes may result in either increased or reduced dry season flows. Effects on dry season flows are likely to be very site specific. It cannot be assumed that it is generally true that afforestation will increase dry season flows.
Caveat. The complexity of the competing processes affecting dry season flows indicates that detailed, site specific models will be required to predict impacts. In general the role of vegetation in determining the infiltration properties of soils, as it affects the hydrological functioning of catchments through surface runoff generation, recharge and high and low flows and catchment degradation remains poorly understood. Modelling approaches which are able to take into account vegetation and soil physical properties including the conductivity/water content properties of the soil, and possibly the spatial distribution of these properties, will be required to predict these site specific impacts.

Examples of ongoing research on the role of forests and water
Four examples are given of ongoing “interactive” research in the UK, South Africa, Panama and India which is addressing questions of policy related to land use change involving forestry and the water environment. Interactive, in this context, implies that the eventual users, or stakeholders, of the research interact closely with the researchers in both the design stage, by helping to define the objectives of the research and by ensuring that the necessary resources are mobilised, and also in the implementation phase by monitoring and steering the research programme. Experience of using this model for the management of applied environmental and hydrological research programmes has shown that it has a number of benefits.

- The users, through close involvement with all phases of the research, assume “ownership” of the programme and are more likely to both “believe in” and “take up” eventual research findings.
- Best use is made of existing knowledge and data resources by building on the collective resources of all the stakeholders.
- The interaction between “users” and “researchers” through stakeholder group meetings not only facilitates linkages and information flows between the users and researchers but also facilitates linkages and information flows between the users themselves. This in itself has often been seen as an important output of the interactive research programme. Increasingly it is being recognised that successful integrated land use and water resources management requires not only a sound science base but also the understanding, commitment and collaboration between the different organisations responsible for and impacted by integrated management.
- The formation of a representative stakeholder group with a diversity of interests and perspectives is more likely to achieve the ultimate goal of integrated land use and water resources management by ensuring that all aspects of development affecting water resources, basin economics, ecology/conservation, socio-economics and the sustainable livelihoods of basin inhabitants are considered and represented.

It is also believed that if stakeholder groups can be formed with representatives comprising both the science and public perceptions this may, through a process of “action learning”, provide a means of reconciling disparate views.

The policy issues that the research programmes are addressing in the UK, South Africa, Panama and India are similar in each country. They relate to how we can best manage both existing and potential forest lands to meet competing demands, particularly in connection with demands for production (e.g. timber and water), conservation, amenity and recreation (CARE) products and for supporting people’s livelihoods. Underlying these policy issues is the value we attach to forests and water products and their impacts on society. 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, from 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 where these are “alien” to the landscape in which they now survive.

The four examples considered below demonstrate the continuing need to improve our understanding of the bio-physical linkages between forests and the water environment, particularly in relation to the impacts on seasonal flows. These examples also illustrate the different degrees of “connectivity” between science and policy in the different countries.

**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.

Although the water quantity impacts of upland afforestation in the UK had been broadly understood by the late 1970s (see e.g. Calder, 1979; Calder and Newson, 1979) it remains 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 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. This study 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. Application of the HYLUC model then allowed the calculation of the range of impacts for different soils and vegetation types. For sand soils and as compared with grassland, these indicated annual average evaporation rates 93 mm greater from broadleaf woodland and 111 mm greater from conifer forest. In terms of the reduction in recharge to the aquifer, the predicted reduction for broadleaf forest was 55% and 66% for conifer forest. For the land area occupied by the whole of the Greenwood Community Forest and over a 24 year period data record (from 1969 to 1993) the calculated average annual reduction in recharge plus runoff resulting from a three-fold (from 9% to 27%) increase in woodland cover was found to be 11%.
A stakeholder group was then formed comprising forest, water and land interests: members of the research team from two UK universities and the UK Forestry Commission and the funding body, (then the Department of the Environment, more recently the Department of the Environment, Transport and the Regions, and now the Department of the Environment, Food and Rural Affairs), the Environment Agency, the local County Council and water company and an agricultural extension agency. Under the direction of the stakeholder group, field studies were initiated in February 1998, at Clipstone Forest, part of the new Sherwood Forest, in the Midlands of the UK to test and refine the scoping study model predictions.

Results from these studies using the calibrated HYLUC model indicate that the initial predictions of the percentage reductions in recharge from forest as compared with grassland were broadly correct. The latest predictions (Calder, 2003; Calder et al., 2003a) indicate that long term recharge rates beneath oak will be reduced by one half (48%) and by three quarters (75%) under pine as compared with grassland (Figure 1). It will be noted that for a year of average annual rainfall no recharge will occur beneath the pine forest. It is only for years of significantly higher than average rainfall and storm events, such as the very wet autumn of 2001, that significant recharge will take place beneath pine forest.

The Clipstone field studies have also indicated concerns over water quality. Concentrations of nitrates in the soil water beneath the rootzone of the pine forest were found to exceed the World Health Organisation’s limits for drinking water. It is understood that in high pollution (industrial) climates the deposition of most atmospheric pollutants, both in the gaseous and particulate forms, are likely to be higher in forests, because of the reduced aerodynamic resistance of forest canopies as compared with those of shorter crops. The high deposition load together with the high evaporation from the pine forest is sufficient to explain the high observed concentrations of nitrate (and chloride). Within the next few decades it is believed that the nitrate “pulse” will reach the water table of the aquifer. 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.

Figure 1  Cumulative recharge plus runoff predicted for a sand soil for grass, oak and pine vegetation covers using the locally-calibrated HYLUC parameter values together with cumulative values of measured rainfall and Penman potential transpiration (right hand scale)
South Africa, 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 government is addressing these issues through policy instruments which include legislation and government funded programmes.

- The National Water Act (RSA, 1998) has declared commercial forestry as a “Stream Flow Reduction Activity” (SFRA), and as such requires that it is managed through the issuing of water use licences and that it is subject to water resources management charges.
- The multi-billion rand Working for Water (WfW) programme (DWAF, 1996) is being implemented for the control and eradication of 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 a major poverty alleviation component, through specifically targeting the poorest in society for employment.

The SFRA legislation and WfW programme highlight 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, such as SFRA and WfW, 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) people’s livelihoods.

These questions are being addressed within the CAtchment Management and Poverty alleviation (CAMP) project in South Africa, Tanzania and Grenada which is being carried out under the direction of a stakeholder group comprising forest, water and poverty interests: members from both UK and RSA universities and research institutes, the South African Department for Water Affairs and Forestry and the Working for Water Programme. The South African focus of the study was chosen to be the Luvuvhu catchment in Limpopo province, which drains into the Limpopo River at the border with Zimbabwe and Mozambique. The Luvuvhu catchment illustrates 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. The project is investigating how different scenarios of forest cover, which may result through application or non-application of WfW and SFRA instruments, will affect the hydrological regime and water availability which will, in turn, affect economic production and people’s livelihoods. Changes in river flow and evaporation, as a result of changing land cover, are being assessed through the use of two land-use sensitive hydrological models, HYLUC (Calder, 2003) and the ACRU Agrohydrological modelling system (Schulze, 1995). Both models have been used extensively in forestry related studies (Calder, 1999; Jewitt and Schulze, 1999) and have been configured for use in the Luvuvhu (Fuller et al., 2003).

In these models, the nomenclature adopted by Falkenmark (1995, 2003) is used to highlight the role of land use on hydrological functioning, with respect to flow out of the catchment, termed “Blue Water” and evaporation, “Green Water” (Figure 2).

To assist the understanding of the linkages between water flows and the economic and “livelihood” value of water when it is used in its green or blue forms, an “evaluation framework” has been devised (Figure 3). This framework is currently being calibrated for the Luvuvhu and will be used to analyse the economic and livelihood benefits of the different forest cover scenarios (later studies will investigate combinations of different forest and irrigation scenarios).
The analysis carried out so far has demonstrated a somewhat unexpected linkage, or rather a lack of linkage, between water availability and livelihood benefit. A “livelihood survey” carried out in the Luvuvhu catchment indicates no statistically significant relationship between poverty (calculated in terms of income rather than expenditure) and greater water access (whether provided through reticulated supply or through being in a higher rainfall area). The implication, from the data presently available, is that, provided the statutory provision of 25 litres of water per capita per day is being met, further provision of water will not greatly increase livelihood benefit. Evidence also suggests that whilst there may be food security gains from increased water provision (e.g. for irrigation of kitchen gardens) the poorest in society are less likely to benefit; wealthy households with greater access to home based reticulated supplies will benefit most (Hope and Gowing, 2003).

Figure 2 Example of how changes in forest cover on the Tengwe subcatchment of the Luvuvhu affect Green and Blue water flows (expressed in units of depth of water over the catchment)
Forests, water and 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. This is 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 massive reforestation (104,000 ha) of the lands in the Panama Canal Watershed that were under agricultural use, primarily livestock production. The report was based on the assumption (perceived wisdom) that the reforestation programme would have a positive impact on water quality and quantity and erosion, and lead to an increase of 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 support 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 together with the hydrological and economic impacts of the proposed change in land use. The Centre for Land Use and Water Resources Research at Newcastle University carried out the scoping study into the hydrological impacts of the proposed land use change (Calder et al., 2001). The study involved the application of the HYLUC spatially distributed evaporation model using local information on land cover and land use and previously published “default” forest and non-forest parameter values (Calder, 1999). The model was shown to be able to describe the recorded flow regime for 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 (~10%) which was essentially commensurate with the experimental error of the observations. The results in terms of cumulative flow for two of the catchments, the fully forested Chagres and partially forested Trinidad, are shown in Figures 4 and 5.

The predicted reduction in runoff on conversion of full pasture to full forest plantation (calculated as cumulative run-off under plantation cover less cumulative run-off under pasture, as a percentage of run-off under pasture) ranged from 18% for the Chagres

![Figure 4](https://iwaponline.com/wst/article-pdf/49/7/39/421098/39.pdf)

**Figure 4** Rio Trinidad, measured cumulative rainfall and runoff together with cumulative runoff predicted by the HYLUC model for the actual land use (21% forest plantations) and for scenarios of full forest plantation and full pasture cover

![Figure 5](https://iwaponline.com/wst/article-pdf/49/7/39/421098/39.pdf)

**Figure 5** Rio Chagres catchment, measured cumulative rainfall and runoff together with cumulative runoff predicted by the HYLUC model for the actual land use (99% forest plantations) and for scenarios of full forest plantation and full pasture cover
catchment (3,420 mm annual rainfall) to 29% for the drier Trinidad catchment (2,222 mm annual rainfall). An initial analysis of the hydrological data, without access to stage discharge calibrations in low flow conditions and with incomplete data on when changes in land use had occurred, was not able to provide evidence for a significant linkage, either positive or negative, between land use and the low flow response. A more detailed analysis, linked also to inverse hydrological modelling comparing observed and predicted seasonal flows, might be able to establish a significant correlation.

However, the study, rather than supporting the conventional wisdom that afforestation would increase flows to the canal reservoirs thus enhancing the capacity of the canal, indicates that annual flows would be reduced and, if there is no significant enhancement of low flows resulting from afforestation, the capacity of the Canal will be reduced by ~10%. Aylward (2002) reviewing the hydrological and socio-economic issues relating to the Law 21 proposals for the Panama Canal concludes that “Further analysis of the low flow issue is therefore essential”.

India – watershed development, forest and water policies

The public perception of the beneficial role of forests in relation to the water environment is very strong in India and this is reflected in government policy. This public perception persists despite the many locally conducted scientific studies which present a different view (see e.g. Sikka et al., 2003).

Policy drivers. The Government of India has long recognised water as one of the most limiting resources to development. In 1987 a National Water Policy was published and this has been recently renewed and updated (Government of India, 2002). A focus of this policy is towards improving water supply to meet the identified water allocation priorities (paragraph 5):

- Drinking water
- Irrigation
- Hydro-power
- Ecology
- Agro-industries and non-agricultural industries
- Navigation and other uses.

The National Water Policy also promotes watershed management and increasing forest cover as a means of “conserving” water. Forestry is regarded as less water demanding in drought prone areas:

(3.4 Watershed management through extensive soil conservation, catchment-area treatment, preservation of forests and increasing the forest cover and the construction of check-dams should be promoted. Efforts shall be to conserve the water in the catchment.)

(19.1 Drought-prone areas should be made less vulnerable to drought-associated problems through soilmoisture conservation measures, water harvesting practices, minimisation of evaporation losses, development of the ground water potential including recharging and the transfer of surface water from surplus areas where feasible and appropriate. Pastures, forestry or other modes of development which are relatively less water demanding should be encouraged. In planning water resource development projects, the needs of drought-prone areas should be given priority.)

Watershed development projects. Since the 1990s some five hundred million US dollars per year have been spent on watershed development programmes (Kerr, 2002) which have
the general aim of alleviating poverty by improving the quality and quantity of water resources. The water component of these programmes has mainly concentrated on improving water “supply” through the construction of new surface water reservoirs (usually termed tanks in India), or desilting existing tanks, and the construction of rainwater harvesting structures, e.g. check dams and contour bunding, which are designed to increase the recharge of water to aquifers. There is ultimately a limit to what can be achieved through “supply side” measures. This limit is reached when surface and groundwater storage schemes, and the exploitation of water from these schemes, is such that there is no flow of water out of the catchment and the catchment becomes, using the International Water Management Institute’s (IWMI) terminology, a “closed” system. Many catchments in India are already “closed” or rapidly approaching this state (see e.g. Batchelor et al., 2000; James, 2002; Batchelor et al., 2003). As catchments approach “closure” two dis-benefits are evident: the cost effectiveness of engineering constructions reduces to nil and flows out of the catchment, which may be required for ecological purposes and for the benefit of downstream users, are lost. When virtually all the resource is utilised, in this “closure” state, there can be no overall benefit obtained through the construction of more storage structures or more measures for increasing aquifer recharge. Upstream users can only “capture” waters at the expense of reduced availability to downstream users within the catchment. When “supply side” options are exhausted improvements in economic and “livelihood” benefits can only be achieved through higher value usage of the existing, nearly fully utilised resource and improved “demand” management.

The beliefs of rural development offices and NGOs, entrusted with implementing these watershed development programmes, that irrigation, soil water conservation measures and forestry are all “good things”, promoted by government policy, and that “more” will therefore necessarily be “better” for the watershed, may have contributed to the present state of affairs of near closure on some catchments. Large scale promotion of these measures within watershed development projects without the promotion of a monitoring and water information system, as required by Government policy, has meant that the detection and recognition of these adverse impacts have been slow or have not even occurred yet.

Clearly it is important that the gap between the institutional and science perceptions of the role of forests and water be closed as considerable amounts of development funds are currently being expended on the erroneous belief that tree planting will increase groundwater recharge within watershed development projects (Calder and Gosain, 2003; Calder et al., 2003b). Equally, if not more serious, is the concern that the present focus on forestry programmes for improving water resources may be diverting attention away from the more urgent need for increased demand management measures for controlling the abstraction of groundwaters for irrigation use. In some southern Indian states groundwater tables, which perhaps three decades ago were within ten metres of the surface and accessible by hand dug wells, now exceed one hundred metres.

The “interactive” research project which has been set up to address these issues with collaborators, government stakeholder departments and NGOs including IIT Delhi, Department of Science and Technology, Winrock International and state government departments and NGOs in Himachal Pradesh and Madhya Pradesh, was initiated in January 2003 and has three components which, taken together, are expected to help close the gap between science and public perceptions.

1. Improve biophysical understanding of the impact of forests on water resources in dry zone regions and to disseminate this understanding, particularly to government, NGO and international development institutions.

2. Improve understanding of “Institutional Perceptions” which underpin forest and water policy – enabling the move to a more science based policy.
3. Create “Dissemination and IT Tools” for communicating the “science perception” and for investigating catchment management options, to be used by stakeholder organisations and local communities.

Conclusions
It is concluded that to move towards a reconciliation of the different perceptions and to put in place better policies and management systems, where policy is better connected with science, and which avoid perverse policy outcomes, will require further efforts to:

1. Understand how the “belief” systems underlying the science and public perceptions have evolved within different stakeholder groups, and to understand how these beliefs may be influenced to enable a more science based policy development process.

2. Develop management support tools, ranging from simple dissemination tools which can demonstrate the impacts of land use decisions on the water environment to institutions and local people, to detailed, robust and defensible hydrological models which are needed to help implement the new land and water policies (such as those now being implemented in RSA, Fuller et al., 2003).

3. Understand better how land and water related policies impact on the poorest in society. It is argued that many present policies may not be significantly benefiting the poor and may even in some situations be resulting in perverse outcomes. Research conducted in the Luvuvhu catchment in RSA indicates that, where in RSA there is a right to free water for each inhabitant (25 l/d), increasing this entitlement, at a large cost to the government, may not significantly increase the livelihood benefits to the poorest people. It is believed that richer people would be most able to benefit from increased supplies. In India, where water policies are such that there is no free entitlement, it is suggested that implementation of present forest and water (and irrigation) policies, which are again very expensive to donors and government, are also mainly benefiting richer communities.

4. Understand better and recognise how different land and water related policies may be affecting the ownership of water resources. Watershed development policies which promote increased infiltration of water through structural measures, for example, checkdams, bunding etc., or non-structural, such as afforestation may be transferring what would have been effectively a common property resource, the water running into a communally owned village tank (reservoir) or into the river (a government owned resource) into an effectively privately owned resource – that of the landowner who can afford the installation of electrically pumped ground water supplies to access locally increased groundwater supplies, or the forest owner whose forest consumes extra quantities of water as compared with most non-irrigated land uses.

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