A note on India's water budget and evapotranspiration

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Some recent analyses of India's water budget are based on information attributed to the Ministry of Water Resources. An examination of the budget components indicates that they imply an evapotranspiration estimate that is significantly lower than what one may expect based on information from other sources. If such is the case, India's water resources situation may be more dire than is otherwise perceived. For, higher evapotranspiration implies correspondingly reduced availability of water for human use. It should be worthwhile to investigate and reconcile the apparent discrepancy between water budget and evapotranspiration, considering the importance of water in the national context.

1. Introduction

India's water budget has been discussed by Gupta and Deshpande (2004), Kumar *et al* (2005), and Garg and Hassan (2007). Additionally, it has also played a role in an expert group report on groundwater management and ownership (Planning Commission 2007). These analyses are based on estimates of water budget components presented in a report by the National Commission for Integrated Water Resources Development Plan (Ministry of Water Resources 1999).

Although water budget is essential for comprehending the status of water availability and use, grasping the significance of the magnitudes of the budget components requires much effort. One way to verify the internal consistency of India's water budget components is to examine the magnitude of evapotranspiration implicit in them, and see if the estimate so arrived is compatible with evapotranspiration estimates from other sources. Such a comparison as presented below, shows that an apparent discrepancy in fact exists between India's water budget and evapotranspiration. The purpose of this technical note is to bring this discrepancy to the attention of the general earth-science community, and to suggest that the discrepancy merits reconciliation through further studies, considering the importance of water budget in the nation's natural resources context. It is hoped that researchers in surface water hydrology, meteorology, and climatology who have the necessary expertise will investigate and help to reconcile the discrepancy.

2. Water budget and evapotranspiration

Water budget, in its elementary form, can be represented by the equation:

$$\begin{aligned}\text{Total rainfall input} = {} & \text{Surface water flows} \\ & + \text{Groundwater recharge} \\ & + \text{Evapotranspiration} \qquad (1)\end{aligned}$$

This equation neglects stream inflows into India from outside its borders. The water budget figures used by the aforesaid authors, based on estimates provided by the Ministry of Water Resources (1999), involve three of the quantities in (1), except evapotranspiration. The magnitudes of the three components are as follows:

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Table 1. *Principal annual components of India's water budget*[1].

Component	Volume (km^3)	Precipitation (%)
Precipitation	3838	100
Potential flow in rivers	1869	48.7
Natural recharge	432	11.3
Available water	$1869 + 432 = 2301$	60
Evapotranspiration	$3838 - (1869 + 432) = 1537$	$100 - (48.7 + 11.3) = 40.0$

[1]Gupta and Deshpande (2004); Planning Commission (2007).

Table 2. *Average annual evapotranspiration as percentage of average annual precipitation for some regions of the world.*

		Evapotranspiration		
Region	Area (10^6 km^2)	ET only (%)	ET + Infiltration (%)	Reference
World's land	148.9	–	60.5–66.4 (3 estimates)	Shiklomanov (1997)
Australia	7.66	90	–	Australian Water Resources (2005)
Amazon basin	6.2	59.4–82.1 (4 estimates)	–	Marengo (2006)
La Plata basin South America	3.2	–	73.2 (1951–1970) 67.7 (1980–1999)	Berbery and Barros (2002)
France	0.55	62.0	82.8	Institut Français de L'Environment (2004)
California	0.41	69.8	–	Department of Water Resources (2005)
United States	9.16	70	–	Leopold (1974)
India	3.28	69.5	74.5	Jain *et al* (2007)
India	3.28	40	51.3	Gupta and Deshpande (2004) Planning Commission (2007)

2.1 *Total rainfall input*

India's average annual rainfall, as seen in Planning Commission (2007), is 1170 mm. India's land area is 3.28 million sq. kms., as seen from the country's profile (National Portal of India 2008). The product of these two quantities yields, for India's total rainfall input, 3838 cu kms. Both Gupta and Deshpande (2004) and Planning Commission (2007) present, for total rainfall input, 4000 cu kms. It seems reasonable to assume that the figure 3838 has been rounded off to 4000.

2.2 *Surface water flows and groundwater recharge*

Of the total rainfall, 1869 cu kms constitutes average annual potential flow in rivers, while 432 cu kms is considered to be replenishable groundwater.

These figures are presented in table 1, along with the magnitude of evapotranspiration implicit in them on the basis of (1). The figures in table 1 imply that evapotranspiration is 40% of total rainfall. The remaining 60% constitutes water accessible for human use. If estimates of India's evapotranspiration from other sources significantly differ from this estimate of 40%, then such a discrepancy should merit careful evaluation and reconciliation.

3. Comparison with other sources

It is common practice to estimate evapotranspiration in two different ways. On the basis of (1), the first is to subtract surface runoff plus groundwater replenishment from total precipitation. The second is to estimate evapotranspiration using mesoscale climate models that use energy balance techniques. By definition, evapotranspiration is that part of rainfall that does not contribute to flow (surface or underground).

Table 3. *Temporal variability of annual average evapotranspiration for two regions.*

	Wet year		Normal year		Dry year	
Region	Period	ET, (%)	Period	ET, (%)	Period	ET, (%)
Amazon basin[1]	1988–1989	65.7%	1982–1983	74.1%	1997–1998	79.0%
California[2]	1998	63.4%	2000	69.8%	2001	90%

[1]Marengo (2006).
[2]Department of Water Resources (2005).

In order to assess the credibility of the evapotranspiration estimate in table 1, we now proceed to compare it with published values of evapotranspiration for six regions of the world with varying areal extent, climatic regimes, and landscape characteristics. In addition, an evapotranspiration estimate for India is presented from a source other than the Ministry of Water Resources. Estimates are also included for the world's land area as a whole. The pertinent data are summarized in table 2, along with their sources.

It is seen from the third column of table 2 that the estimates for evapotranspiration alone, exclusive of subsurface recharge, vary between 59.4 and 90 per cent, significantly larger than the 40% implied in Gupta and Deshpande (2004), and Planning Commission (2007). It is also worth noting that Jain *et al* (2007) give an estimate of 69.5% for India's evapotranspiration. Clearly, estimates of evapotranspiration are subject to methodological limitations and uncertainties. Even accounting for these uncertainties, it is apparent that the estimate 40% inherent in Ministry of Water Resources (1999) appears to be a significant underestimation of India's evapotranspiration.

4. Temporal and spatial variability

Evapotranspiration, just as precipitation, is subject to variability in space and time. For a credible comprehension of long-term water resource availability, it is necessary to have an understanding of these variabilities in addition to the average annual estimates.

Evapotranspiration will vary noticeably from year to year, depending on whether precipitation for a given year is above or below normal. Marengo (2006) and Department of Water Resources (2005) provide estimates for temporal variation of evapotranspiration for the Amazon Basin and for the state of California respectively. Their findings, presented in table 3 show that between wet and dry years evapotranspiration varies from 65.7% to 79% for the Amazon Basin, and 63.4 to 90% for California. If these estimates are any indication, India's evapotranspiration may in fact exceed the 69.5% indicated by Jain *et al* (2007) during years of below-normal rainfall.

5. Discussion

In the last section it has been shown that an estimate of 40% for India's evapotranspiration implicit in Gupta and Deshpande (2004) and Planning Commission (2007) is significantly smaller than published estimates for a number of regions in the world, varying widely in land area, climatic setting and landscape. In particular, Jain *et al* (2007) estimate India's evapotranspiration to be 69.5%, almost 30% larger than the other estimate. In as much as evapotranspiration represents consumptive use (that is, water not available for human use), larger evapotranspiration implies correspondingly reduced availability of water amenable for human use. As seen from table 1, the 40% evapotranspiration estimate corresponds to 2301 cu kms of available water. However, consistent with their evapotranspiration estimate, Jain *et al* (2007) estimate available water to be 1460 cu kms (1260 cu kms of surface flow plus 200 cu kms of groundwater recharge). The difference, 842 cu kms, constitutes an almost 37% reduction in the expected water availability.

The foregoing discrepancy has major implications to India's water resources planning. India's 'estimated utilizable water resources' is 1122 cu kms (Gupta and Deshpande 2004; Planning Commission 2007). This constitutes 48.8% of the available water resources of 2301 cu kms (table 1) implying that, for technological and environmental reasons, a little less than half will be actually amenable to extraction for human use. Finally, current water use in India is estimated to be 634 cu kms, which is 56.5% of 'estimated utilizable water resources'. Based on this, one could infer that India's water demand will outstrip supply a few decades from now.

Instead, if we were to use the estimate of 1460 cu kms for available water, and assume 48.8% extractability, then 'estimated utilizable water resources' reduces to 712 cu kms from 1122 cu kms.

If we compare this 712 cu kms with the current use of 634 cu kms, it is clear that India is already at the threshold of over development of water resources. Thus, India has to be seriously concerned about shortage of water right now, rather than a few decades from now.

If the arguments presented above are reasonable, what needs to be done now? The suggestion is that the earth-science community comprising hydrologists, soil scientists, meteorologists, and climatologists would do well to devote attention to generate a water budget in which the components, including evapotranspiration, are mutually consistent. To this end, it will be necessary to critically evaluate available stream flow data and infiltration data. Complementing this, independent estimates of evapotranspiration need to be made based on mesoscale climate models. Garg and Hassan (2007) report that water resources data are treated as classified material by the government. If so, the effort could be impeded by difficulty of data access.

6. Concluding remark

India's water budget, as provided by the Ministry of Water Resources (1999), is widely used as the basis for making projections about India's water future, and related policy matters. There is sufficient evidence to suggest that the budget estimates may be seriously overestimating available water resources and utilizable water resources. It is hoped that this technical note would motivate researchers in surface water hydrology, meteorology, and climatology to revisit India's water budget and provide credible revised estimates, which would be of broad interest to earth scientists, water managers, policy makers and the concerned citizens.

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