Journal of Hydrology 518 (2014) 140–149

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Do water-saving technologies improve environmental flows?

Charles Batchelor [a,*], V. Ratna Reddy [b], Conor Linstead [c], Murli Dhar [d], Sumit Roy [d], Rebecca May [c]

[a] Water Resources Management Ltd, West Byfleet, UK
[b] Livelihoods and Natural Resource Management Institute, Hyderabad, India
[c] WWF-UK, Woking, UK
[d] WWF-India, New Delhi, India

ARTICLE INFO

Article history:
Available online 21 December 2013

Keywords:
Environmental flows
Water-saving technologies
Water use efficiency and productivity
Consumptive and non-consumptive water uses
Governance
India

SUMMARY

Water saving and conservation technologies (WCTs) have been promoted widely in India as a practical means of improving the water use efficiency and freeing up water for other uses (e.g. for maintaining environmental flows in river systems). However, there is increasing evidence that, somewhat paradoxically, WCTs often contribute to intensification of water use by irrigated and rainfed farming systems. This occurs when: (1) Increased crop yields are coupled with increased consumptive water use and/or (2) Improved efficiency, productivity and profitability encourages farmers to increase the area cropped and/or to adopt multiple cropping systems. In both cases, the net effect is an increase in annual evapotranspiration that, particularly in areas of increasing water scarcity, can have the trade-off of reduced environmental flows. Recognition is also increasing that the claimed water savings of many WCTs may have been overstated. The root cause of this problem lies in confusion over what constitutes real water saving at the system or basin scales. The simple fact is that some of the water that is claimed to be 'saved' by WCTs would have percolated into the groundwater from where it can be and often is accessed and reused. Similarly, some of the "saved" runoff can be used downstream by, for example, farmers or freshwater ecosystems. This paper concludes that, particularly in areas facing increasing water scarcity, environmental flows will only be restored and maintained if they are given explicit (rather than theoretical or notional) attention. With this in mind, a simple methodology is proposed for deciding when and where WCTs may have detrimental impacts on environmental flows.

1. Introduction

Environmental flows are the flow regimes needed to sustain aquatic ecosystems. They encompass the magnitude, quality, and timing of water flows required to maintain the components, processes, functions, and resilience of aquatic ecosystems that in turn can provide water and other ecosystem services to people (Hirji and Davis, 2009). As such, they are a core element of good practice in water resources management and the operation of infrastructure used in water supply, storage and treatment. In most cases, it is politically, economically and socially impossible for initiatives or policies aimed at restoring and/or maintaining environmental flows to return river systems to a pristine state. Instead account is taken of competing demands and uses for surface and ground water and judgements are made regarding environmental flows that are influenced by the social, economic and political value that is attributed to healthy and functional freshwater ecosystems (Dyson et al., 2003).

In India, public investment in dams, irrigation systems and inter-basin transfer systems (in some cases as part of the National River Linking Project) along with massive private investment in borewells and submersible pumps have had a major influence on the hydrology of river basins (Biggs et al., 2007; Shah, 2013). To complicate matters further, it is likely that medium-term factors (e.g. climate change, commercialisation of agriculture, pollution, etc.) will put additional stress on freshwater ecosystems and users of ecosystem services. As a consequence of these and other factors, freshwater ecosystems are under increasing pressure and more vulnerable ecosystems are being damaged by increased demand for and consumptive use of both surface and groundwater (Varma, 2011).

Contested debates over environmental flows often arise when major infrastructure projects, especially dams, diversions and abstractions are being planned, designed, constructed or operated (Hirji and Davis, 2009; Le Quesne et al., 2010). In contrast, the potential impact of WCTs on environmental flows receives minimal attention. In part because WCT's tend to be small in scale and their potential detrimental impacts on those upstream and downstream are often more diffuse, less well understood and, in general, more difficult to quantify or monetise.

* Corresponding author. Tel.: +44 1932 351234.
E-mail address: BatchelorCH@gmail.com (C. Batchelor).

0022-1694/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jhydrol.2013.11.063

WWF's[1] interest in India's river basins is driven by increasing concern over the current state of environmental flows and users of eco-system services. WWF (India), with support from the European Union, has been implementing a project that is exploring linkages between changing farming practices and environmental flows.[2] In this paper, we argue that a greater awareness is warranted of the current plight of India's freshwater ecosystems and the benefits that are derived from them. More specific objectives of this paper are: (1) To review current literature regarding potential impacts of WCTs on environmental flows and (2) To propose a simple decision-support methodology for identifying watersheds or river basins in which increased use of WCT's could be problematic.

2. Current policies and programmes

India's national water policy is formulated by the Ministry of Water Resources. With respect to environmental flows, the draft 2012 National Water Policy (GoI, 2012) states:

Ecological needs of the river should be determined, through scientific study, recognizing that the natural river flows are characterized by low or no flows, small floods (freshets), large floods, etc., and should accommodate developmental needs. A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated ground water use.

In terms of water use priorities, the 2012 National Water Policy ranks "minimum ecosystem needs" fifth after safe water for drinking and sanitation, other domestic water needs, water for achieving food security and water for sustenance agriculture (GoI, 2012). In the earlier 2002 National Water Policy, ecology was ranked fourth after drinking water, irrigation and hydropower (GoI, 2002).

3. Regional and International WCT experience

WCTs are important elements of India's Twelfth Five Year Plan (Shah, 2013). It is envisaged that increased use of WCTs will play a central role in enhancing the productivity of rainfed agriculture and that improvements in irrigation efficiency will free-up water for other uses (Shah, 2013). Support for irrigation-related WCTs is based on a widely-held view that traditional irrigation schemes have efficiencies that are in the range 30–40%. However, as argued succinctly by Perry (2007), low irrigation efficiency figures can provide a false sense of water wasted that often prompts recommendations for technological upgrades or irrigation modernisation in the belief that improvements in efficiency will reduce losses and free-up water for alternative uses (Molle and Turral, 2004; Perry et al., 2009; Van Halsema and Vincent, 2012). However, evidence is building to indicate that this belief is ill-conceived when applied to irrigation water use at the system or basin scale (e.g. Seckler et al., 1996; Wallace and Batchelor, 1997; Seckler et al., 2003; Molle and Turral, 2004; Perry et al., 2009; FAO, 2012; Chambers, 2013). A characteristic of beliefs or conventional wisdom is that they are stubbornly resistant to contrary evidence. In this case, conventional wisdom linked to irrigation efficiencies has remained in place despite the best efforts of the International Water Management Institute (IWMI), the UN's Food and Agriculture Organisation (FAO) and others for a decade or more. More to the point, in this review, we have found plenty of evidence that well-managed WCTs can improve the productivity of water use (i.e. useful biomass produced per unit volume of water) but no evidence that water has been freed up for downstream uses.

The root cause of misunderstandings over irrigation efficiency lies in confusion over issues of scale and what constitutes a water saving at the irrigation system or basin scales (FAO, 2012). More specifically, some of the water that is claimed to be 'saved' by WCTs would have percolated into the groundwater from where it can be accessed and reused by farmers or other water users. Similarly, some of the runoff that is claimed to be "saved" is often used downstream by farmers or other users. Perry (2007) traces the development and use of various irrigation efficiency concepts back to the classical irrigation efficiency theories developed by Israelson and others in the 1950s. Israelson (1950) defined irrigation efficiency as the ratio of the water consumed by crop to the water diverted to irrigate that crop and, despite later modification, this ratio has remained the underlying basis for estimating irrigation efficiency ever since. Importantly, the classical concept of irrigation efficiency ignores the potential for return flows and recycling of water "lost" as drainage. The net result is that efficiency of water use computed at the system or basin scale will in most cases be higher than the efficiency at the field or plot scale.

Later contributions to the debate on irrigation efficiency emphasised the use of ratios or fractions to describe water use and to consider explicitly the impact of return flows (e.g. Willardson et al., 1994; Allen et al., 1996). Further development of this approach (e.g. by Perry, 2007; Perry et al., 2009; Frederiksen and Allen, 2011;) led to the proposal by Pereira et al. (2012) that total water use[3] in a specified domain can be divided into six fractions (see Fig. 1). Accordingly, total water use can be divided into the consumed fraction, comprising of beneficial consumption and non-beneficial consumption. The remainder can be classified as the non-consumed fraction comprising of recoverable and non-recoverable fractions that can further be subdivided into beneficial and non-beneficial fractions. Some typical examples of the fractions of total water use are provided in Table 2. When identifying fractions, it is important to specify the boundaries (in time and space) of the domain of interest and to ignore reuse and recycling of water within the boundaries of this domain. A key point here is that under this system, environmental flows can be classified as beneficial consumption, beneficial recoverable or beneficial non-recoverable fractions depending on the context and geographical location of the specified domain.

In summary, not all the water purportedly 'lost' from an irrigated field or an irrigation scheme constitutes a loss to the hydrological system as a whole. Gyles (2003) argues that confusion over water savings arises from '*…errors in logic and the inability or reluctance of the promoters* (of WCT) *to view water flows in a systems context*'. However if the intent of a WCT programme is to 'save' water or to free it up for other uses, it is vital to know whether the 'losses' from an irrigation scheme or a farming system are in fact losses at all (e.g. Crase and O'Keefe, 2009).

4. Water accounting

Water accounting has developed from two distinct perspectives—irrigation engineering and hydrology (which, in this case, is taken to include hydrogeology) (Perry et al., 2009). Both the

[1] World Wildlife Fund For Nature.

[2] For more information on the WWF's Thirst Crops Programme see: http://www.wwf.org.uk/what_we_do/safeguarding_the_natural_world/rivers_and_lakes/where_we_work/south_asia/india_thirsty_crops.cfm.

[3] Total water use (TWU) is defined as the sum total of water used or applied for a specified class of users or uses (or a combination of classes) within the spatial and temporal boundaries of a specified domain (e.g. within the boundaries of an irrigation scheme over the period of a crop season). TWU includes irrigation, rainfall and, if relevant, takes changes in net storage into account (e.g. changes in residual soil moisture content of the root zone). TWU does not include recycling or reuse of water within the specified domain.