INTERNATIONAL COMMISSION
ON IRRIGATION AND DRAINAGE

Eighteenth Congress
Montreal 2002

Q. 51
R. 5.04

IMPACT OF IRRIGATION ON DRINKING WATER AVAILABILITY IN SRI LANKA

IMPACT DE L'IRRIGATION SUR LA DISPONIBILITE DE L'EAU POTABLE AU SRI LANKA

Eline Boelee[1] Wim van der Hoek[2]

ABSTRACT

In the Uda Walawe irrigation system in the dry zone of southern Sri Lanka, residents have dug shallow wells for domestic water supply next to canals. Several of these shallow wells, and nearby tube wells as well as the surface water were sampled for water quality testing. Reservoirs and canals had higher levels of bacteria and parasites than shallow wells and tube wells. Salinity and fluoride levels were highest in tube wells. Combining the four indicators, shallow wells offer the best quality for drinking water and are preferred by the population because of taste, availability, easy access and reliability. This most favorable domestic water supply turns out to be highly dependent on irrigation water management. Some wells fall dry between cropping seasons, which suggests that groundwater in the wells is recharged by seepage from irrigation canals. This is confirmed by detailed groundwater measurements and calculations. Water levels were measured in shallow wells and piezometers at varying distances from the canals, before and after lining. Groundwater levels closely followed changes in canal water releases and canal seepage accounted for 74% of groundwater recharge. After concrete lining of the canals, people in this rural area are facing increasingly restricted availability of good quality water. Consequently, the irrigation rehabilitation program is threatening the most favorable source of domestic water and with it the health of the population. This study clearly indicates the need for inter-sectoral planning and management of water

1 Irrigation and health specialist, International Water Management Institute, P.O. Box 2075, Colombo, Sri Lanka, phone: +94-1-787404, fax: +94-1-786854, e-mail: e.boelee@cgiar.org.

2 Epidemiologist, International Water Management Institute.

resources. More efficient irrigation management does not serve the rural population if it deprives them off their best source of drinking water.

RESUME ET CONCLUSIONS

Sur le périmètre irrigué Uda Walawe situé en zone sèche au sud du Sri Lanka, les résidants ont creusé des puits peu profonds à côté des canaux d'irrigation pour satisfaire leurs besoins domestiques. Certains de ces puits s'assèchent entre les périodes de culture, laissant supposer que les puits sont rechargés en eau grâce à des infiltrations provenant des canaux. La disponibilité en eau de ces puits peu profonds est menacée car l'agence d'irrigation a prévu de bétonner les canaux pour économiser l'eau en réduisant les fuites.

Le long d'un canal de distribution, les niveaux d'eau ont été mesurés dans 28 puits peu profonds et 30 piézomètres à différentes distances des canaux, avant et après que ces derniers aient été cimentés. Entre juin 2000 et décembre 2001, le niveau de la nappe souterraine a été mesuré au moins une fois par semaine. Le niveau de l'eau dans les canaux et l'excédent d'eau d'irrigation ont été aussi contrôlés. Le gradient hydraulique a été calculé à partir de mesures journalières durant les mois secs (juin et juillet 2000) au cours desquels l'eau est attribuée par rotation.

Des échantillons ont été prélevés au niveau des puits peu profonds, des forages et des eaux de surface pour tester la qualité de l'eau. La potabilité de l'eau a été mesurée en évaluant la contamination par les coliformes fécaux, la salinité, la présence de parasites et les taux de fluor.

Les réservoirs et les canaux contenaient plus de bactéries coliformes thermotolérantes et de parasites protozoaires que les puits peu profonds et les forages. Les forages étaient les ouvrages les moins contaminés par les bactéries mais présentaient les salinités les plus élevées. En revanche, les taux de fluor étaient à leur maximum dans les forages. Si on prend en compte les quatre indicateurs, l'eau de meilleure qualité pour la boisson est fournie par les puits peu profonds. Ces derniers sont par ailleurs préférés aux autres sources d'eau par la population pour des raisons de goût, de disponibilité, de facilite d'accès et de fiabilité. Par contre, ils dépendent énormément de la gestion de l'eau d'irrigation.

Les niveaux de la nappe dans les puits et les piézomètres suivent de très près les lâchers d'eau dans les canaux. Les fuites dans les canaux sont responsables de 74% de la recharge de la nappe. Entre les périodes de culture, les niveaux d'eau moyens hebdomadaires variaient surtout du fait de pluies irrégulières. Après avoir cimenter le canal, le niveau de l'eau souterraine est toutefois remonté. Par contre, à la moitie du canal de distribution, dans une zone d'habitation, le niveau n'est pas remonté jusqu'à son niveau antérieur. Bien que l'année ait été relativement sèche, cette baisse de niveau est probablement liée au fait que le canal ait été cimenté puisque le niveau de l'eau souterraine a l'extrémité du canal a atteint pratiquement le même niveau que l'année précédente.

Par conséquent, le programme de réhabilitation qui consiste à cimenter les canaux d'irrigation menace la meilleure source d'eau domestique et avec elle la santé des populations. Cette étude met en évidence la nécessité d'une approche intersectorielle pour la gestion de la ressource en eau. Pour économiser l'eau, il faut développer des stratégies alternatives qui considèrent le bassin versant de manière intégrée, et prennent en compte les usages non-agricoles de l'eau d'irrigation. Une gestion plus efficace de l'irrigation ne profite pas aux populations rurales si elle les prive de leur meilleure source d'eau potable.

1. INTRODUCTION

In many irrigation schemes in Sri Lanka and elsewhere, residents have dug shallow wells for drinking water supply next to canals. It was reported from the Uda Walawe irrigation system in southern Sri Lanka, that several of these wells fall dry between cropping seasons, which suggests that groundwater in the wells is recharged by seepage from irrigation canals. The irrigation agency has planned to extend the irrigated area to provide more people with irrigation water alongwith the associated benefits. According to water balance studies for the Uda Walawe irrigation scheme, the amount of water available from the reservoir and tributaries cannot irrigate the area to be developed newly, unless measures are taken to improve irrigation performance in the existing command area (SAPI, 2000). One of the measures to achieve this goal is the concrete lining of irrigation canals to reduce seepage, increase conveyance efficiency, and reduce weed growth. Together, this should increase the quantity of water available for irrigation of the extension area.

Where a high groundwater table causes water logging and salinization, a reduction of seepage can be a positive change. However, in other situations such as in Uda Walawe, the risen groundwater table created an opportunity for perennial vegetation, including fruit trees outside the irrigated areas and for construction of wells to exploit the groundwater. In these cases, lining could have negative effects (Van der Hoek *et al.,* 1999).

In order to assess the influence of canal lining on the availability of water in shallow wells, groundwater levels were monitored close to a canal before and after lining. Several water quality indicators were measured to assess the suitability of different water sources for drinking: contamination with fecal coliform bacteria, salinity, presence of parasites and fluoride levels. A survey among school children had revealed that 45% of 14-year old school children had signs of dental fluorosis, probably caused by high concentrations of fluoride in drinking water. Fluorosis is a defect in the formation of tooth enamel in children, resulting in irreversible mottled teeth and possibly bone deformities.

2. METHODOLOGY

Study area

The Uda Walawe irrigation scheme in southern Sri Lanka consists of a large dam and reservoir with a capacity of 268 million m^3 and is managed by the Mahaweli Authority (MASL), a government agency. The reservoir feeds two principal canals, the right bank main canal, with a command area of 11444 ha and the left bank main canal, serving some 7000 ha. A 12000 ha extension area is being developed at the downstream area of the left bank. Releases into the left bank main canal equal $233*0^6$ m^3 for the existing irrigated area, which requires $229*10^6$ m^3 (SAPI, 2000). The study area is situated along the left bank canal near the town of Suriyawewa (Figure 1).

Uda Walawe is generally considered part of the dry zone, receiving rain during the Northeast monsoon season, mainly between October and December (Figure 2). Annual rainfall in Suriyawewa over the period 1990-2000 ranged from 853 to 1423 mm, with an average of 1148 mm (Department of Meteorology, Colombo, Sri Lanka, 2001). The relative humidity in the area is around 77%, with an average temperature of 28^{o}C (JICA, 1993).

Uda Walawe has two cropping seasons, the main season from October to February, and a second season from April to August. Rice is the main irrigated crop, followed by banana, which has been actively promoted by government agencies as a means of saving water. In addition, the risen groundwater table enables farmers to grow perennial crops, especially coconut in home gardens adjacent to the canal.

Irrigation water is scheduled by rotation within the distributor canals. Only at the start of the season the canals carry water every day for land preparation. Between cropping seasons, the canal is closed for one to two months, which are usually March, April, August and September.

Use of water for non-agricultural domestic purposes has been taken into account in the design of the irrigation system by constructing concrete steps at several sites along large canals to allow access to the water for washing and bathing purposes. When the canals are closed, water for domestic purposes is collected from reservoirs or natural streams. Water for drinking and cooking is obtained mainly from shallow wells, of which there are many, close to the irrigation canals. In addition, drinking water is taken from tube wells, which are deep (> 20 m) public bore holes fitted with casing and a hand pump. Few villages are connected to the piped water supply system and individual connections are too expensive for most households. Most of the water treatment plants in Uda Walawe, including the one in Suriyawewa, use irrigation water.

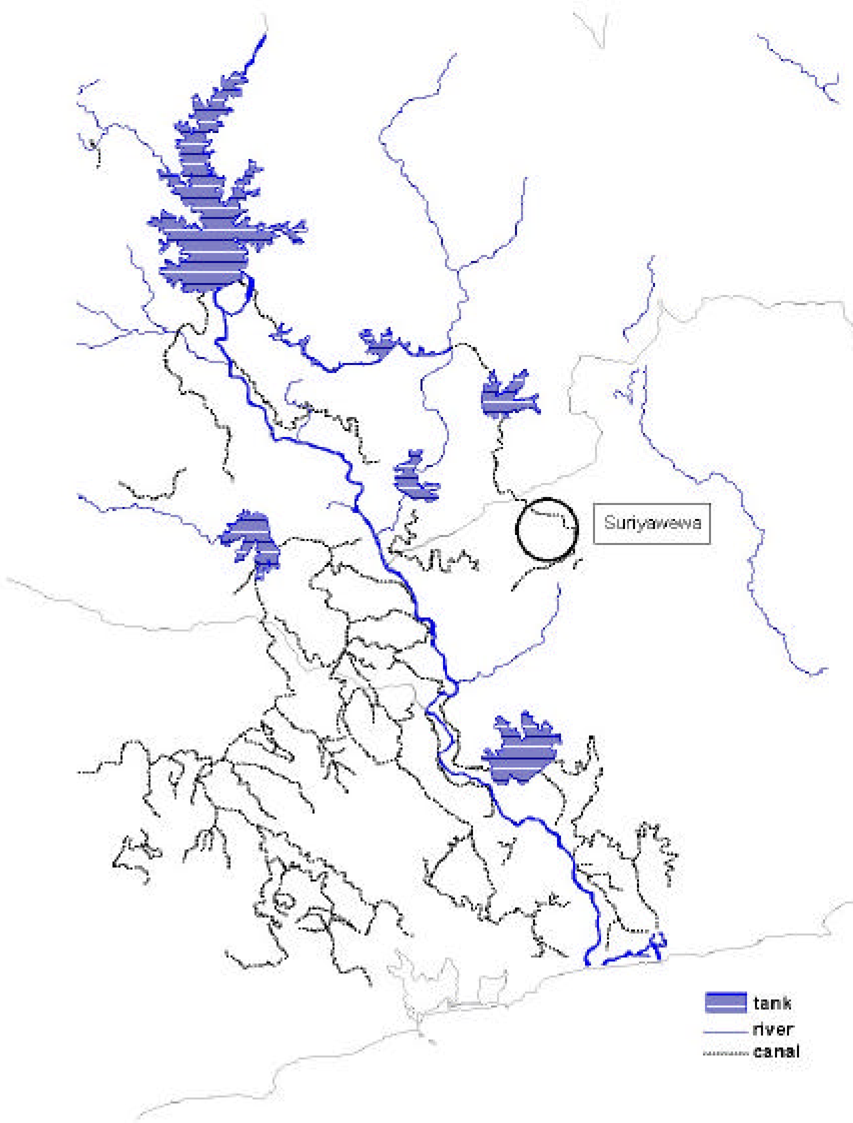
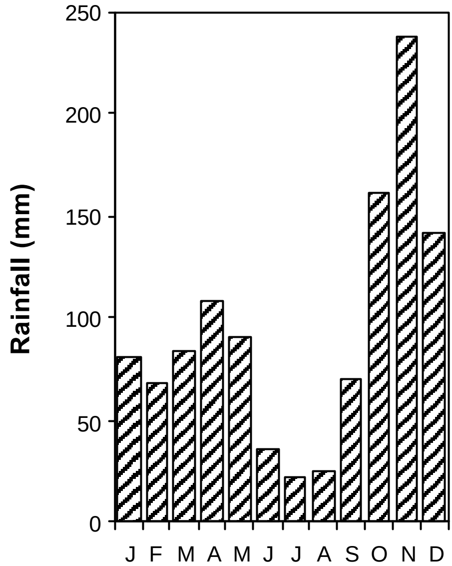


Figure 1. Uda Walawe irrigation scheme in southern Sri Lanka with the Suriyawewa study area (Périmètre irrigué de Uda Walawe au Sud de Sri Lanka, avec la région d'étude Suriyawewa)

Water quality analysis

Water sampling for bacterial analysis was done in 3 tube wells, 12 shallow wells, 8 canal sites and 3 reservoir sites in the command areas of distributors MD17 and BBD5. Three 200 ml samples from each location were taken once per month between August and December 2000. At the time of sampling, electrical conductivity



Source : Department of Meteorology, Colombo, Sri Lanka, 2001.

Figure 2. Mean monthly rainfall in Suriyawewa, Sri Lanka, over the period 1990-2000 (Précipitation mensuelle moyenne à Suriyawewa, Sri Lanka, pendant la période 1990-2000)

was measured in the water source, and again in the laboratory. The water samples were analyzed for the presence of thermotolerant coliform bacteria using the membrane filter technique as outlined by Csuros and Csuros (1999) and the American Public Health Association (1998). Large volume (49 l) samples were concentrated by filtration and examined by microscopy for the presence of two intestinal parasites, *Giardia* spp. cysts and *Cryptosporidium* spp. oocysts.

Fluoride levels have been determined in 114 samples from tube wells, dug wells, irrigation canals, surface ponds and piezometers in Uda Walawe using a field probe, followed by precise titration in the laboratory. Fresh water samples in tube wells were collected after five minutes of pumping through a flow cell, while for shallow wells a bailer was used. Electrical conductivity was measured as an indication of salinity.

Groundwater measurements

Along the distributor canal MD17, water levels were measured in 28 shallow wells and 30 piezometers at various distances from the main and field canals. Between June 2000 and December 2001, the level of groundwater in this grid was determined at least once a week and water levels in canals and irrigation water releases were monitored. Between February and April 2001, the unlined canal was replaced by a lined one consisting of prefabricated elements.

Seepage q (groundwater flux in m^2/d) from irrigation canals has been estimated for the period June/July 2000 with Darcy's equation :

$$q = -KD\frac{\partial H}{\partial x}$$

The hydraulic gradient $\partial H/\partial x$ (m/m) was found by measuring absolute water levels at several distances from the canals. The KD value (with K = hydraulic conductivity in m/d and D = depth of the aquifer in m) was estimated by measuring the changes in groundwater levels after opening and closing of the canal according to Ritzema (1974). During the study period, water was distributed in rotation, which offered an excellent opportunity to investigate the effects of fluctuations in the canal on groundwater levels. Percolation from rice fields was estimated by assuming a percolation rate of 5 mm/day for low humic gley soil (JICA, 1993). This was then multiplied by the irrigated area in MD17 (51.5 ha). The resulting KD values for the main, distributor and field canals are presented in Table 1. The calculated groundwater flux, or seepage rate, is multiplied by the length of the different canals in the MD17 area.

Table 1. Seepage to groundwater from canals in the MD17 command area, Uda Walawe, Sri Lanka, based on daily measurements in June and July 2000 (Pertes d'eaux des canaux, sur la zone du canal MD17, en direction de la nappe d'eau souterraine à Uda Walawe, Sri Lanka, basé sur les mesures en Juin et Juillet 200)

	Median KD (m^2/day)	Gradient $\partial H/\partial x$ (m/m)	Canal length L (m)	Seepage qL (m^3/day)
Main canal	26.4	-0.012	290	92
Distributor canal	23.4	-0.044	524	1,079
Field canals	34.9	-0.022	2,400	3,685

Source : Meijer, 2000.

3. RESULTS

Water quality in different sources

Surface water sources, reservoirs and canals, had higher levels of thermotolerant coliform bacteria, than the groundwater sources-shallow wells and tube wells (Table 2). The canal samples had the highest and tube wells the lowest levels of contamination ($p<0.05$). The bacterial content of tube well water was never above 150 ThCU/100ml and sometimes conformed to the national and international drinking water standard of 0 ThCU/100 ml (Democratic Republic of Sri Lanka, 1983; WHO, 1996). More than 40% of the reservoir samples and over 80% of the shallow well samples fell above the 1000 ThCU/100 ml, Sri Lanka standard for bathing waters.

Table 2. Average values of indicators of water quality in different sources of domestic water in Uda Walawe, Sri Lanka (Valeurs moyennes d'indicateurs de la qualité de l'eau pour différentes sources d'eau domestique à Uda Walawe, Sri Lanka)

Source of water	Thermotolerant coliform bacteria (ThCU/100 ml)	Parasites[a] (in 49 l)	Salinity (mS/cm)		Fluoride (mg/l)
			S[b]	UW[c]	
Tube well	17		0.69	1.46	1.53
Well		356			
Shallow well	2506		0.29		
• Unprotected	3645			1.10	1.09
• Protected	227			1.10	1.33
Surface water		2172		0.28	0.39
• Canal	920		0.17		
• Reservoir	1623		0.25		
N	26[d]	4[e]	26[d]	114	114

Sources : Meijer, 2000, Shortt, 2001 and Rajasooriyar (unpublished results).

[a] *Giardia* spp. cysts and *Cryptosporidium* spp. oocysts.
[b] In Suriyawewa, measured with bacterial sampling in 2000.
[c] In Uda Walawe, measured with fluoride sampling in 2001.
[d] Average over 5 sampling rounds in 2000.
[e] Average over 3 sampling rounds in 2000.

The tube wells had higher salinity levels than the other water sources, sometimes as high as 13.5 mS/cm. In 40% of the tube well samples in Suriyawewa the salt levels were above the national standard for drinking water of 0.75 mS/cm (Democratic Republic of Sri Lanka, 1983).

The four sources of water were contaminated with cysts and oocysts; 11 out of 12 analyzed samples contained protozoan parasites. Surface water sources contained more than six times the number of protozoans in tube wells and shallow wells. Although, numbers of oocysts were low (<15/49l) in both types of wells, the mere presence of one pathogenic organism would make these water sources unacceptable for drinking by WHO standards (WHO, 1996).

Fluoride levels increased from surface water to groundwater sources and were highest in tube wells, with maximum up to 5.8 mg/l. The WHO standard for drinking water is 1.5 mg/liter (WHO, 1993). However, it has been argued that this is too high for hot climate countries where people drink more water. For Sri Lanka an upper limit of 0.8 mg/liter has been proposed (Warnakulasuriya et al, 1992). This makes water from tube wells as well as from shallow wells unsuitable for consumption in Uda Walawe.

Groundwater fluctuations

Groundwater levels closely followed changes in canal water releases. Within 15 - 20 m from the distributor, groundwater levels rose only hours after water was released at the head of the canal. When the canal was closed for a few days, groundwater levels dropped rapidly. Figure 3 shows that the groundwater at 8 and 15 m from the canal fluctuated over some 0.2 - 0.4 m with the canal water levels. The groundwater dropped sharply at the end of the rainy season, sometimes more than 1.5 m, which may be below the bottom of the well.

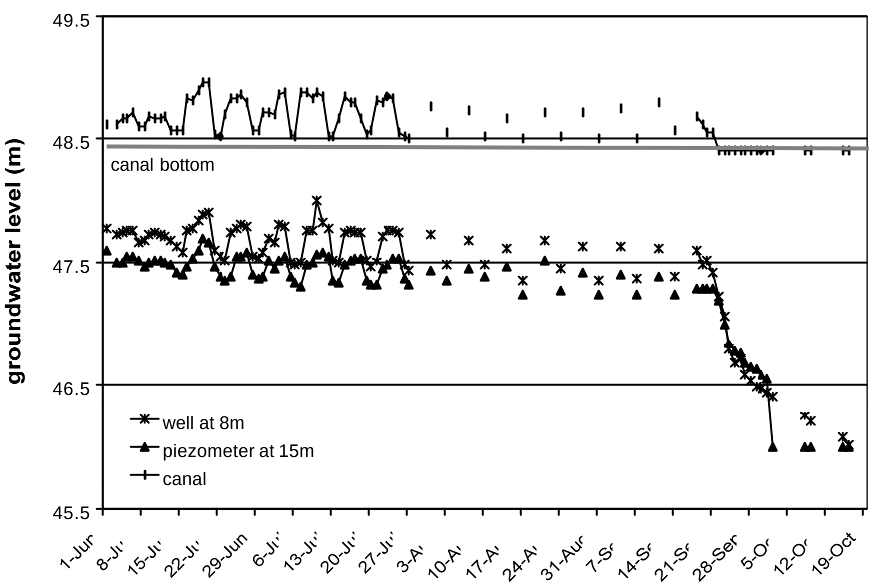


Figure 3. Daily groundwater and canal water levels halfway MD17, Suriyawewa, Sri Lanka, in 2000 (Niveaux journaliers de la nappe phréatique et du canal, à mi-longueur du canal MD17 à Suriyawewa, Sri Lanka, en 2000)

During the intercropping season, weekly average water levels fluctuated over 0.5 – 1.5 m, related to the irregular rainfall ($p<0.05$; Figure 4). After rehabilitation of the canal, groundwater levels rose again. However, halfway the distributary canal, in a settlement area, it did not rise back to the same level as before the rehabilitation

(Figure 5). This was most probably due to lining of the canal and not to the relatively dry year, as groundwater near the tail end of the canal had risen to almost the same level as the year before (Figure 6).

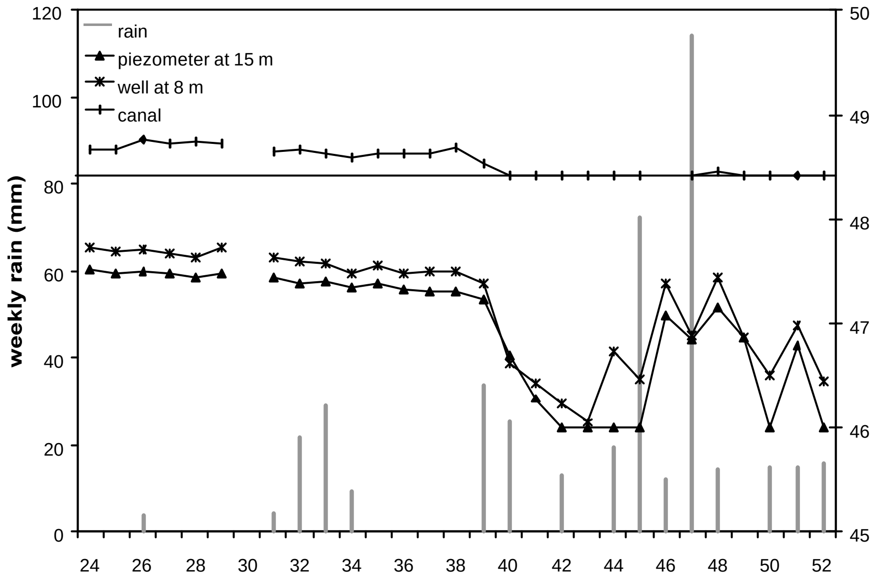


Figure 4. Weekly rainfall and average groundwater and canal water levels halfway MD17, Suriyawewa, Sri Lanka, in 2000 (Précipitations hebdomadaires et niveaux moyens de la nappe phréatique et du canal à mi-longueur du canal MD17 à Suriyawewa, Sri Lanka, en 2000)

The contribution of canal seepage to groundwater recharge was estimated in Table 3. Both canal seepage and infiltration from rice fields played a role in groundwater recharge, be it at different rates as suggested by the difference between figures 5 and 6. In June and July 2000, dry months without rain, about one quarter (26%) of the total groundwater recharge in the MD17 command area was due to infiltration from irrigated fields and three quarters (74%) to canal seepage. This implies that if lining would reduce seepage from the distributor and field canals by 60% (Goldsmidt, 1989; Kraatz, 1997), total recharge of the groundwater would be reduced by 43%.

4. DISCUSSION

Shallow wells contain the best quality drinking water of all sources in the area. They have lower levels of salinity and fluoride than tube wells, and lower concentrations of fecal coliform bacteria and parasites than surface water from canals

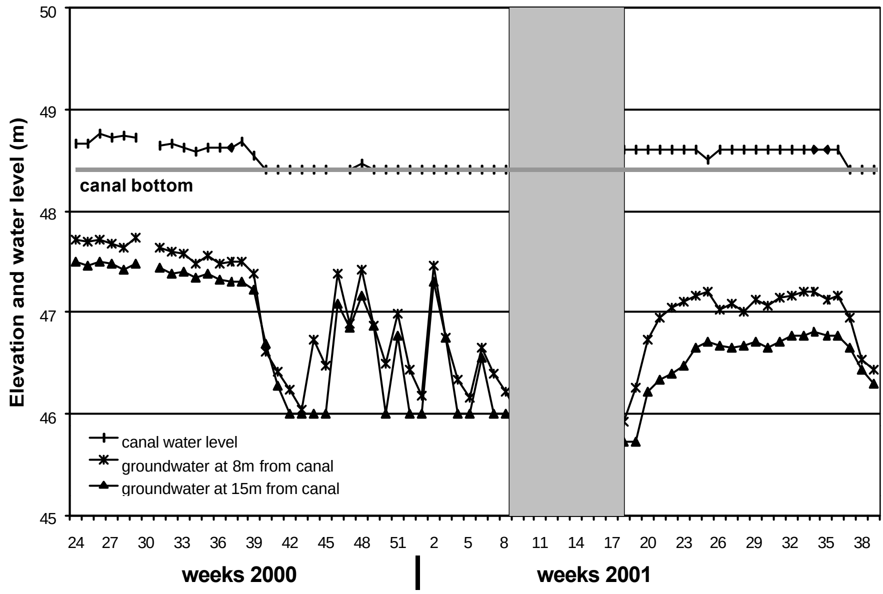


Figure 5. Weekly average groundwater and canal water levels halfway MD17, Suriyawewa, Sri Lanka, before and after rehabilitation of the canal between week 8 and 18 of 2001 (Niveaux moyens hebdomadaires de la nappe phréatique et du canal à mi-longueur du canal MD17 à Suriyawewa, Sri Lanka, avant et après réhabilitation du canal, entre les semaines 8 et 18 de 2001)

Table 3. Contribution of seepage from canals and rice fields to groundwater recharge in June and July 2000 in MD17, Suriyawewa, Sri Lanka (Contribution des fuites provenant des canaux et des rizières à la recharge de la nappe phréatique sur le canal MD17 à Suriyawewa, Sri Lanka, en Juin et Juillet 2000)

	Estimated seepage (m^3/day)	Number of days filled with water (days/year)	Estimated average recharge (m^3/day)	Contribution to total recharge (%)
Main canal	92	300	76	2
Distributor canals	1079	250	739	16
Field canals	3685	250	2524	56
Total seepage from canals	4856		3339	
Field percolation	2125	200	1164	26
Total estimated recharge	6981		4503	100

Source : Meijer, 2000.

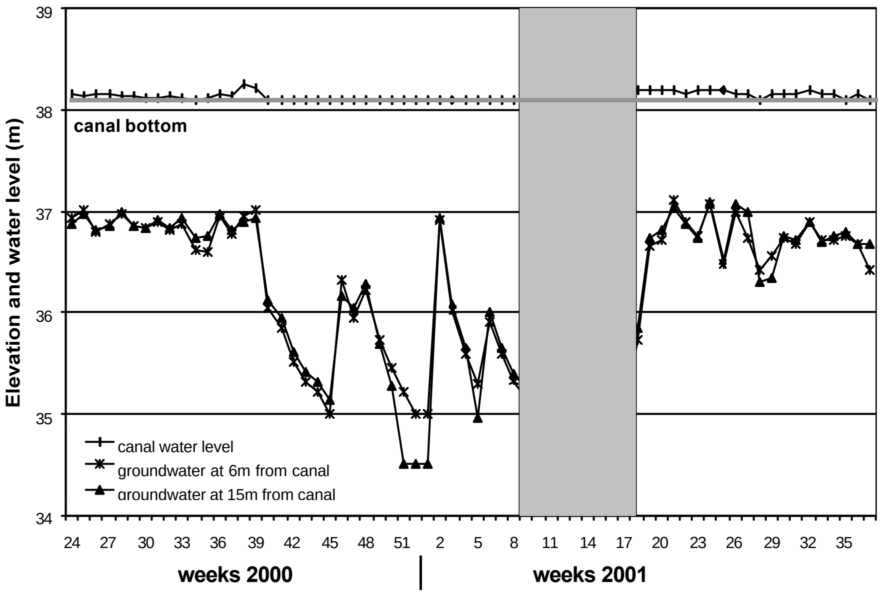


Figure 6. Weekly average groundwater and canal water levels at the tail end of MD17, Suriyawewa, Sri Lanka, before and after rehabilitation of the canal between week 8 and 18 of 2001 (Niveaux moyens hebdomadaires de la nappe phréatique et du canal au bout de MD17 à Suriyawewa, Sri Lanka, avant et après réhabilitation du canal entre semaine 8 et 18 de 2001)

and the reservoir. The presence of protozoan parasites and thermotolerant coliform bacteria indicates contamination of surface water and groundwater with human or animal excreta. Exposure to this contaminated water may be reduced by simple water treatment before consumption such as boiling, disinfection, or slow sand filtration. The removal of excess salts or fluoride is a more difficult and costly process.

The shallow wells offer the best quality water as well as a reliable and steady supply. The abundant wells are a readily available source of water for drinking and other purposes. Between cropping seasons however, water levels in the wells drop sharply and people have to look for other sources.

In the dry months of June and July 2000, when daily measurements were done to determine the contribution of different canal types to groundwater recharge, most of groundwater recharge could be attributed to seepage from canals. Percolation from rice fields accounted for only 25% of recharge. Figure 4 suggests, that the effect of rainfall can be quite significant in the inter-cropping season, when irrigation canals are closed.

The results show that irrigation management does affect the availability of water for domestic purposes in Uda Walawe. During the time between the two growing seasons, the canals are dry and no longer available for bathing and laundry. In addition, water levels in shallow wells drop sharply and fluctuate with the irregular rainfall pattern. This temporary phenomenon might become chronic after lining of all distributary canals. Residents may be forced to look for alternative water sources and may have to revert to untreated surface water from larger canals, rivers and reservoirs. As a result, people may spend more time collecting water of inferior quality further from their houses. This may reduce the quantity of water used in the household, contributing to reduced hygiene and increased risk of disease (Esrey et al. 1991). Hence, the irrigation rehabilitation program of lining canals is threatening the most favorable source of domestic water and with it the health of the population.

If canal lining would be interrupted in settlement areas, shallow wells would continue to be recharged with canal seepage. The lined stretches of the canal might still reduce water losses and improve water delivery efficiencies. However, this may not be sufficient to increase total water availability in the Uda Walawe irrigation system and more creative solutions are required to safeguard water for the planned extension area. A combination of less water demanding crops, especially on permeable soils, improved field water management and a better use of return flows might result in more substantial water savings.

This study clearly indicates the need for inter-sectoral planning and management of water resources. Planners of water resources development projects should take a holistic view and recognize that irrigation water is used for many purposes such as drinking water supply, perennial vegetation, livestock, and fisheries. More efficient irrigation management does not serve the rural population if it deprives them off their best source of drinking water.

ACKNOWLEDGEMENTS

This paper is to a great extent based on the work of three students: Rebecca Shortt from McGill University, Karen Meijer from the University of Twente and Lorraine Rajasooriyar from the University of East Anglia. All studies were carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada. French translations by Anne Bichard.

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