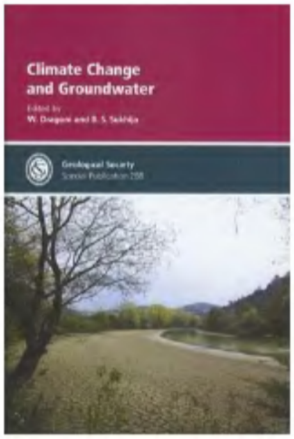

Climate Change and Groundwater. W. Dragoni and B. S. Sukhija (eds). Geological Society, Special Publication 288. The Geological Society, London, 2008. xiii + 186 pp. Price: £75.

A change of climate or 'climate change' has been attributed to alteration in the composition of the global atmosphere due to the growing greenhouse gas emissions on account of the growing human activities and this is in addition to natural climate variability observed over comparable time periods[1]. Climate change will particularly affect the world's shared freshwater resources altering the amount and distribution of river resources. Due to this, riparian states suffer decreased freshwater availability, apart from acute crises, such as flooding or drought that impair food production, endanger public health, stress established settlement patterns and jeopardize livelihoods and social well-being. Groundwater maintains surface water systems through flows into lakes and base flow to rivers, which are crucial for maintaining the sensitive ecosystems. However, all these functions become increasingly vulnerable as changes in climate occur. This has seen the ecologic and socioeconomic consequences in recent years.

The interaction of groundwater and surface water has been shown to be of significant concern in issues related to water supply, water quality and degradation of aquatic environment. In this context, groundwater resources are of primary importance because they are one of the best protected reserves of water for distribution and also contribute water to streams and rivers during the recession period, in the winter and summer. Variations in temperature and precipitation during the year will have a direct impact on changes in groundwater levels, reserves and quality. Indirectly, climate change will influence irrigation with water extracted from aquifers, which would alter hydrological systems, regional land uses and agricultural practices[2,3]. Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems[4]. During the 20th century, precipitation totals have mainly increased over land in high northern latitudes and decreased in some sub-tropical and lower mid-latitude regions. Global average air and ocean temperatures have also increased and over the past 50 years hot days, hot nights and heat waves have become more frequent and it is predicted that these trends will continue into the 21st century[4]. It is not only precipitation totals which are likely to change but also precipitation intensities and variability. The frequency of heavy precipitation events has increased whilst the area of land classified as dry has more than doubled since 1970s (ref. 4). These climatic extremes are likely to cause increased frequencies of severe droughts and floods.

This necessitates the immediate policy interventions by every country to implement appropriate mitigation measures to minimize the social and environmental disruptions worldwide. Even if countries do undertake immediate and rapid action to reduce their emissions, some degree of climate change is inevitable. Abilities to deal with weather extremes in the present day are considered to be very limited, the situation may get worse in the future. Therefore, the need is to significantly improve ability to plan and adapt to extreme events such as floods, droughts, cyclones and other meteorological hazards.

'*It is not the strongest of the species nor the most intelligent that survives.*
It is the one that is the most adaptable to change.'

Charles Darwin (1809–1882)

The book under review is a compilation of 13 papers of a special session organized by International Association of Hydrologists (IAH) Working Group on Groundwater and Climate Change on 'Impact of Climate on Groundwater Resources' during the XXXII International Geological Congress (at Florence, Italy, during August 2004). This book is relevant considering the latest Assessment Report from the Intergovernmental Panel on Climate Change (IPCC), wherein it was acknowledged that groundwater use will increase as a result of the declining availability of surface water and increased global water consumption and that 'there has been very little research on the impact of climate change on groundwater' (IPCC 2007). The book attempts to draw the attention of the fundamental research related to understanding groundwater resources in the context of global warming.

Groundwater is the world's largest accessible store for freshwater yet groundwater remains largely peripheral to current analyses and discussions of climate change and adaptation. This situation is mystifying since groundwater is the primary source of drinking water to nearly half of the world's population and, as the dominant source of water to irrigated land, is critical to global food security. However, spatial and temporal changes in groundwater levels in an aquifer are conditioned by both anthropogenic and natural factors. The enhanced human activities driving the climate change have manifest effects on groundwater systems, including groundwater storage, recharge and discharge rates are evident in recent times. Groundwater has been the mainstay for meeting the domestic needs of more than 80% of rural and 50% of urban population, besides fulfilling the irrigation needs of around 50% of irrigated agriculture. It has been estimated that 70–80% in India and 40% of the world's food produced comes from groundwater irrigation. Contribution from groundwater to India's Gross Domestic Product (GDP) has been estimated at about 9%.

Dragoni and Sukhija provide a comprehensive review of 'climate change and groundwater' with a synthesis of the IPCC findings that are relevant to the field of hydrogeology in the first chapter. The authors argue that neither the impacts of climate change on water resources nor the possibilities offered by groundwater to mitigate drought are new, but for the global dimension of the environmental change and its permanency. Compared to the climatic changes of the past, the present change is taking place in a world where many vast areas are densely populated with a higher water demand. The focus of the chapter is on the focal areas of hydrogeological research in order to mitigate the likely impending impacts.

Benderev *et al.* discuss some aspects of groundwater regime in Bulgaria, southeastern Europe with respect to climatic variability. The data from National Hydrogeological Network (NHGN) provide ample evidence of major drop in recharge to the aquifers during 1982–94 drought period and also for decrease of groundwater resources. Karst and shallow porous aquifers in these regions showed their vulnerability to long-lasting droughts. The groundwater in karst regions was most affected by the reduction of recharge due to direct linkages between surface and groundwater sources in carbonate terrains. The second chapter highlights the need for investigating the groundwater resources and their vulnerability to droughts. Drought analysis constitutes a major issue for drought policies and implementation of strategies for minimizing the impacts of drought.

Ducci and Tranfaglia evaluate the region of Camapania, southern Italy to estimate the influence of climate change upon the hydrological regime, variations in the water budget prompted by precipitation and temperature changes. They owe a mean decrease of 30% average infiltration in carbonate aquifers with the declined flow of springs to marked reduction of precipitation distribution during the last two decades coupled with an increase of 0.3°C in regional temperatures. The rise in temperature and decrease in precipitation have had a sequence of direct effects on the hydrologic cycle, with particular regard to the evapotranspiration rate, soil moisture, surface runoff and ultimately the groundwater recharge and discharge. The groundwater resources account for 86% of Italy and 99% of Campania's drinking water requirements. Based on the decline of 37 m^3/s during the last three decades, the projection indicates a dismal scenario of 70% decline of groundwater resources in the next 50 years. This emphasizes the need to ascertain the availability of groundwater resource, required for effective water management, in terms of both a reduction in water consumption and also for exploring alternate water supplies. This trend is confirmed by Polemio and Casarano in the third chapter based on data for the period 1821–2003 from 126 rain gauges, 41 temperature gauges, eight river discharge gauges and 239 wells in southern Italy. A widespread decreasing trend of annual rainfall is observed over 97% of the whole area from 1921 to 2001. The cross-correlation with piezometric level shows that the variability of groundwater is explained in terms of rainfall, rainfall and river discharge variability. The trend of groundwater availability is negative everywhere and worrying due to decline in recharge with the increase in discharge by wells to compensate the non-availability of surface water tapped by dams, as a direct effect of droughts.

Ludue-Espinar *et al.* analyse the spatio-temporal variability of groundwater through spectral analysis of watershed measurements on a network of parameters in the Vega de Granda aquifer in southern Spain show decadal, 3.2 year, annual and semi-annual cycles apart from establishing the relationship between the surface drainage network and the aquifer recharge as a reflection of the climate. This emphasizes the importance of long-term monitoring of piezometric levels to adopt appropriate strategies in groundwater management.

The development of past civilizations and the foundation of towns have always been linked to the availability of water. Rapti-Caputo and Helly analyse geological, hydrological, hydrogeological and historical data (of more than 2000 years of evolution) of Yperia Krini spring in Thessaly, Central Greece by investigating variations in terms of water discharge. This integrated analysis indicates that Yperia Krini spring has little storage capacity and is very sensitive to rainfall variations. Strong social and political decline in Yperia Krini spring is attributed to climate changes that have influenced the whole Mediterranean area.

Changes in surface flow regime and changes in recharge to groundwater interact to affect ground and surface water levels. Groundwater contributes to baseflow in streams and hence changes in the groundwater regime are likely to have detrimental effects on fisheries and other biota due to altered baseflow dynamics. In the seventh chapter, Scibek *et al.* quantify the impact of climate change on groundwater in an unconfined aquifer (that is strongly influenced by surface water) and develop adaptive strategies for climate change under the auspices of Natural Resources Canada Climate Action fund. Groundwater levels near the river floodplain are predicted to be higher earlier in the year due to an earlier onset of peak flow, but considerably lower during the summer months. Away from rivers, groundwater levels increase slightly due to predicted increase in recharge. Future climate scenarios suggest a shift in the hydrograph peak to an earlier date, although the peak flow remains the same, and baseflow level is lower and of longer duration.

Geyh and Ploethner discuss the origin of a freshwater groundwater body in Cholistan, Thar desert, Pakistan through a comprehensive hydrological, geophysical and isotope hydrological survey conducted during 1986–1991. The study provides a hydrogeological concept on the origin and recharge of the fresh groundwater body while illustrating indirect recharge of fresh groundwater during flash floods in low lands during the last pluvial period rather than directly replenished in the high mountain areas far in the east.

All present groundwater discharges have both recent (<100 years) and past groundwater recharge components (>100 years). The ratio of the present to the past groundwater recharge depends on the climate zone and hence at low recharge rates transient, and at high groundwater recharge rates steady state conditions prevail. The consequences of the present trend of climate changes will continue in subsurface beyond 21st century, even with the drastic reduction of greenhouse gas emissions now because of the delayed response of all large reservoirs such as the atmosphere, oceans, ice shields and groundwater systems. All input changes in such large reservoirs will trigger a transient behaviour. Transient response of groundwater systems to climate changes is analysed by Seiler *et al.* This helped in assessing optimal yield of groundwater resources which is required for developing sound groundwater management strategies.

In the tenth chapter, Sinha and Navada establish that the recharge to shallow groundwater to direct infiltration of precipitation and/or through river channels during episodic floods through environmental isotopic studies in the arid region of Rajasthan. Radiocarbon measurements of groundwater along palaeochannels in Jaisalmer district revealed that these sources were recharged a few thousand years ago indicating the potential sources of groundwater to palaeochannels or buried river courses. Negligible modern recharge and over exploitation in recent times have led to the deterioration of groundwater quality in the Bhadka–Bheemda district.

Case studies of Arad and Jericho in arid, semi-arid regions by Issar highlight the role of groundwater availability consequent to climate changes in deciding the survival of cities. Global warm period and consequent spelled dryness in Arad, resulted in inhabitants dependent on a local perched horizon deserting the region. However due to availability of perennial spring fed by a regional aquifer from a large area of eastern Judean mountains, Jericho continued to flourish since prehistoric times. At Jericho, the transition from a socio-economic system of hunters and gatherers to that of farmers was enabled by technical innovation of irrigation. This study emphasizes the magnitude of the impact and its duration playing a decisive role apart from the society's ability to withstand vagaries of climate change that depend on the total resilience of its societal and natural subsystems.

Salgot and Torrens suggest groundwater recharge with reclaimed water to mitigate the shortages in southern European countries. While cautioning on the risk-related environmental impacts, they highlight the likely benefits such as improvement of reclaimed water quality, increased storage capacity, reduced evaporation losses, reduction in seawater intrusion, etc.

Baseline climate and different exposures to climate stimuli in different regions decide the vulnerability of humans to climate change apart from adaptive capacity of the population, their management skills and resource availability. The final chapter by Sukhija reviews adaptive methods for sustaining groundwater through droughts apart from suggesting adaptation strategies for sustaining groundwater resources, which include identifying deep aquifers resilient to droughts and artificial groundwater recharge through percolation ponds. However, identification of deep confined aquifers with large groundwater potential could be a challenging exercise.

Assessment of vulnerability and consequent risk to water resources due to climate-change impacts is necessary to work out proper adaptation and mitigation responses. It is necessary to adapt groundwater management accordingly and to consider the particular resilience of most larger aquifers as a buffer for climate change, considering the complexity of the linkage between climate change and groundwater. In this context, this book provides the information concerning the impacts of climate change on groundwater. This book could have included case studies from all continents than focusing mostly on European countries. Still it constitutes a good reference book for researchers across the globe. It portrays the 'state of science' with the comprehensive overview of the current insights and knowledge on possible impacts and associated technical and management challenges due to climate change through case studies. Furthermore, it also gives options for developing and safeguarding groundwater resources and the human benefits derived from them.

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3. IPCC, Impacts, adaptation and vulnerability. Contribution of the Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (eds McCarthy, J. J. *et al.*), Cambridge University Press, UK, 2001, p. 1000.
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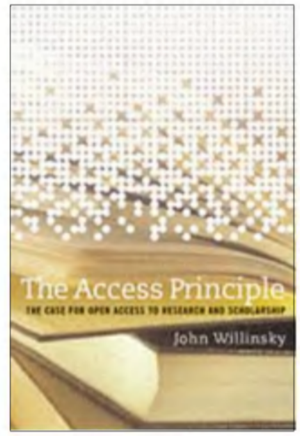

The Access Principle. The Case for Open Access to Research and Scholarship. John Willinsky. The MIT Press, Hayward Street, Cambridge, MA 02142-1493, USA. Paperback. 2006. xv + 287 pp. Price: US$ 16.95.

John Willinsky is the Khosla Family Professor of Education at Stanford University. A votary of the open access movement, his book, *The Access Principle* published in 2006 has won a number of awards for its scholarship.

At its heart is a simple idea, that 'a commitment to scholarly work carries with it the responsibility to circulate that work as widely as possible'. This is in part so that knowledge that is created can be disseminated in a manner that the largest numbers of people have unfettered access to it, but there is more to it than just that. . . .

The issues that Willinsky deals with have wider ramifications. For instance, who 'owns' knowledge? The scholar who creates it through research, or the funding agency that funded it directly or indirectly, or the commercial publishing house who owns the journal where the research was reported? And how best can it be used for public good, while ensuring that all involved parties do not go unrewarded or unrecognized?

The book is very timely: the digital revolution is upon us all in a way that demands that such issues be thought about afresh since the modes of preservation of information and the modes of dissemination of knowledge have changed radically in our lifetime. For one thing, most journals of any quality are now online. Furthermore, many of them are 'open access', namely the articles they carry can be viewed without a subscrip-