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Overview about Long-Term Levels Variations of Groundwater in Worldwide

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Abstract

Analysis of long-term data of groundwater levels is required to provide an insight into the reaction of groundwater resources to climate variability, land use changes, human activities and consumption. In recent decades the increasing use of groundwater and natural extremes had resulted in lowering of its level in large parts of the world. In addition, it has been increasingly threatened in quantity and quality. For maintaining sustainability of groundwater resources, it is important to understand aquifer storage change in long-term. Many studies had showed under different conditions how groundwater levels change with time. This review presents long-term variations of aquifer quantity worldwide. It shows three aspects: main factors that impact groundwater level variations, applied methods to evaluate these variations and the situation of groundwater.

Keywords: Groundwater level; Temporal variation; Long-term analysis

Introduction

Groundwater constitutes in many countries a main source of drinking water and is a vital resource to sustain agricultural, industrial, and domestic activities. It ranges from 50 to 70% in Italy [1], Portugal and France, exceeds 70 % as in Austria, Belgium, Switzerland and Germany and until more than 75% in the United States of America. It's characterized by its high quality due to its good protection from the pollution and the evaporation. It's also increasingly used in irrigation and agricultural especially in countries that have a scarce in surface water resources (for example South Africa (84%), Spain (80%), Mexico (64%), Greece (58%), etc. However, the increasing use of groundwater for anthropogenic activities, such as land use, irrigation, pumping has resulted a considerably lower in groundwater levels in large parts of the world. Additionally, it has induced a significant destruction in its quantity and quality and pose impacts on the ecosystem. Moreover, the high cost in management of groundwater resources is derived from the increasing of the extracting cost due to the drawdown in groundwater level, which could be amplified to violent changes causing social and economic problems in region developments [2-7]. Assessment of groundwater level in long-term scale, which provides insight in the reaction of groundwater resources to climate variability, land use changes, human consumption and irrigation is fundamental to solve many important problems related to protection of groundwater, its availability and sustainability.

A large number of studies showed under different conditions how groundwater levels change by time. For example, several researches focused on the role of climate change in groundwater recharge rate [8-29].

Chen et al. had illustrated how climate change affects groundwater recharge, additionally hazards of drought period lead to depletion in aquifer storage by evapotranspiration, evaporation, pumping for consumption and irrigation, reduction in precipitation. Considering that there is a wide agreement about the continuation of increasing global warming causing shifts in water tables. Furthermore, beside climate change, a number of studies highlighted by the data that land use change and human activities for domestic water supply and agriculture irrigation significantly correlated with groundwater levels. Hence lacked good management of water resources will lead to reduction in aquifer storage [30-44]. This paper outlines previous studies related to groundwater levels changes during long-term, which helps to forecast potential risks could match.

Highlight on Groundwater Situation

Understanding the long-term data sets of aquifer storage variability is a critical to provide insight into the reaction of groundwater resources to environmental conditions and maintaining sustainable [45]. Thereby, groundwater situation in worldwide and potential methods to assess have been synthesized in Table 1. This table reviews some anterior studies that carried out on groundwater levels change for 39 basins in 20 different countries during long-term. It shows the used methods of groundwater levels changes evaluation, main factors that could impact and make a change in its levels and its situation under processes dominating its dynamics and thus potential future risks.

Climate and land use changes are undoubtedly the main factors. It is generally assumed that any change in temperature and precipitation could alter groundwater recharge and cause shifts in water tables as a first response to climate change.

The pressure on water resources has increased, it could be shown that besides the climatic fluctuations, land use changes groundwater levels tend to decline because of the intensive human use and his activities also with environmental changes. The relative importance of each of these factors depends on time and place. Groundwater levels are significantly correlated with multitude of factors including landcover, soil characteristics, geology, landscape characteristics, and water use [5].

Site	Basin	Time-series	Main factor	Methods	Situation of groundwater	Source
USA	State-wide Texas, 9 major and 21 minor aquifers in Texas	1930s-2000s	Extensive land-water use	Geospatial and statistical methods	Reduction in water level from about 14 m to 36 m	Chaudhuri and Ale [33]
USA	"LANSING, MICHIGAN in the Saginaw aquifer"	1961-1990 to simulate for 2030	Climate change	General circulation models for Climate by Canadian CCCMA GCM and Hadley GCM	19.7% recharge rate reduction using the CCCMA GCM whereas 4.1% increase using the Hadley GCM whatever pumping conditions.	Croleg and Luukkonen [13]
USA	Illinois	1983-1992	Climate change	Observation data on regional scale	Dryer summers have huge impacts on groundwater levels	Elfatih, et al. [16]
USA	The High Plains aquifer for eight States	1950-2009	Overexploitation of aquifer withdrawals	Water-level measurements for mapping water-level	Decline in water level average	McGuire [49]
USA	Makaha valley Hawaiian watershed	1960 -2008	Pumping		Reduced the water level in the high-level aquife	Mair and Fares [39]
USA	Black Mesa basin, Arizona	The past 31 k.y	Climate change	Using 14C dating of groundwater and numerical simulation of ground-water flow	Recharge rates varied significantly 2-3 times higher than today and water levels fluctuated by about 80 m	Zhu, et al. [29]
USA	Texas High Plains Ogallala Aquifer	1958-2000	Withdrawals from the Aquifer for irrigation		Decline of wells yields	Colaizzi et al. [34]
USA	Edwards Balcones Fault Zone aquifer, Texas	1947-1990 simulation 2050	Climate change	Link large-scale climatic processes to basin-scale ground water dynamics	Aquifer will endanger under climate scenario even the pump rate stays steady	Loaiciga et al. [24]
USA	Rattlesnake Creek basin	1955-1994 1995-2035	Evaluating long-term water-management strategies	Watershed model SWAT and the ground-water model MODFLOW model known as SWATMOD	The model is capable to predict well the observations data	Sophocleous et al. [51]
USA	Isthmus between Crystal Lake and Big Muskellunge Lake (Wisconsin)	1954-1994	Annual recharge	Groundwater flow model	Fluctuations in recharge rate	Kim et al. [47]
Canada	1- Northern Saanich Peninsula 2- Armstrong, semiarid southern part of British Columbia"	1975-2002	Ability to evaluate and predict groundwater level	Non-linear model (Wavelet Volterra coupled model). With comarate to other methods	The groundwater has nonlinear behavior	Maheswaran and Khosa [55]
Canada	Carbonate aquifer, southern Manitoba	From 1961	Climate variability	Cross-correlation	The erratic behavior of precipitation and temperature lead to reducing the recharge rate to the groundwater	Chen et al. [10]
Canada	Grand River watershed (Ontario)	40 years	Climate change	Hydrologic model HELP3	The potential recharge rate of groundwater is predicted to increase by 100 mm/year	Jyrkama and Sykes [22]
Australia	Gnangara Mound in the northern Perth	1914 to 1969 1970-2005	Climate change		Decreasing of groundwater levels since 1969 to 2005	Commander and Hauck [11]

Australia	Wakool Irrigation District	SINCE 1981	Pumping (waterlogging and salinization caused by raising piezometric level)	Linear programming models (PUMPMAN-I and PUMPMAN-2) MODFLOW	Irrigation and inadequate drainage produce raising water-level	Punthakey et al. [41]
France	Picardie	1966 to 1983	Levels variations is influenced by recharge rainfall variations	Modeling by lumped parameter hydrological model	Satisfactory match between observed and simulated data	Thiery [52]
France	The Lorraine Triassic Sandstone Aquifer on the eastern limb of the Paris Basin Moselle departmen	1970-2009	Pumping effect on baseline water quality	Model hydrogeologic of groundwater management of Triassic sandstone aquifer of Lorraine	After shortage from 1970 to 1980, the total volume of groundwater abstracted has decreased by about 46% in 2013	Celle-Jeanton et al. [2]
United Kingdom	Lambourn (representing Chalk), and the Teme (representing Triassic sandstone)	1951 to 1980	Climate change	Generalized aquifer/river model and two climate change scenarios	Aquifers would affect by reduction at low flow with modification in hydrological regime,	Cooper et al. [12]
United Kingdom	Coltishall in East Anglia, Gatwick in southeast England and Paisley in west Scotland	1961-1990 2011-2100 (2020s, 2050s and 2080s time periods)	Climate change	Using the UKCIP02 'high' gas emissions scenario	Flooding during winter periods, and drought during dry periods	HerreraPantoja. and Hiscock [20]
Germany	Northrhine-Westfalia	Since 1982	Climate change	A statistical model to make regional climate scenarios	There will be reduction of groundwater recharge a 15 to 25% in 2050	Kriiger and Ulbrich [23]
Switzerland and Germany	Northern Switzerland and southern Germany	30 yr with a monthly resolution	Climate change	MIKE SHE models	Role of several elements affecting groundwater dynamic (meteorological conditions and land use changes also pumping activity and feedback mechanisms	Stoll et al. [27]
Italy	Venice multi-aquifer system	More than 40 years	Land use changes, overexploitation and climate change		Water levels are under natural values	Da Lio et al. [35]
Italy	Campania region	20 years	Reduction in precipitation	GIS	Decrease of 30% of average infiltration	Ducci and Tranfaglia [14]
Europe	European catchment	1961 to 1990	Climate change	SWAT-G	Decreases of groundwater recharge and streamflow are predicted	Eckhardt and Ulbrich [15]
Japan	Tokyo metropolitan area	1890-1990	Climate change	Using deep borehole temperature data	Groundwater level is fluctuated	Taniguchi [28]
Japan	Beppu	40 yr until 1967	Surexploitation	Data	A decline of piezometric head	Yusa et al. [44]
India	Orissa	1994-2003	Climate change	Geostatistical methods	Strong correlation between groundwater levels and rainfall beside high temperature	Panda et al. [25]
India	The Nethravathi River basin	1980-1996	Excessive pumping	Geostatistical methods		Reghunath et al. [43]
India	Northe west India	2003-2012		Combined Satellite gravity data and model estimate of water storage changes	Depletion of groundwater	Chen et al. [46]
Syria	Five villages	The last three decades	Extensive ground-water exploitation	Data collected by ICARDA	Groundwater will continue to decline especially under climate change models	Aw-Hassan et al. [31]

Turkey	Köyceğiz-Dalyan Watershedwas	1970 to 2010	Climate change and irrigation	SWAT model and Climate change and land use scenarios	Decrease in groundwater recharge	Ertürk et al. [17]
Tunisia	Sfax	1997-2006	Climate change	Geostatistical analysis and PCA tool and Cross-correlation	Decreases continuously in zones whilst steady increase in others thank to artificial recharge	Triki et al. [50]
Tunisia	Mornag	1971-1999	Overexploitation	Observed data	Water-level depression	Charef et al. [32]
Sultanate of Oman	Barka	1984 to 2003	Heavy pumping	Autocorrelation and cross-correlation functions	Decrease continuously the wells water level and advancement of saline-fresh water interface	Rajmohan et al. [42]
Jordan	The Azraq basin	1950-1990	Excessive pumping		The water-level declines	Dottridge and Abu Jaber [36]
Saudi Arabia	The Umm Er Radhuma	1967- 1990	Pumping for domestic uses and irrigation	Numerical simulation and hydrogeochemical investigations	Piezometric level decreased about 4 m	Abderrahman and Rashhduddin [30]
Niger	The Continental Terminal water-table near Niamey	1991 and 1994	Land uses	Simple model of perfect mixing in the saturated zone	Groundwater resources have increased by up to 150% Since 1960s	Leduc et al. [48]
Korea	Jeju Island	1992-2009 Baseline 1961-2009 Drought	Climate-land use change	Soil Water Balance (SWB) computer code	The largest recharge under baseline scenario	Mair et al. [40]
Ghana	Nabogo Basin	1980-2007	Sustainability	GMS-MODFLOW	For now no significant role in the regional water balance	Lutz et al. [38]

Table 1: Some studies to evaluate groundwater quantity change in worldwide.

Quantity Evaluation of Aquifers

Using different scenarios of global change, land cover and agricultural practices, could provide more information about the future risks on groundwater resources [46-50]. They are usually analyzed by driving hydrogeological models using predicted climate and management parameters taking into account the changes scenarios [2,13,47-55].

In addition, measurements in the field are used to quantify this evaluation like stable and radioactive isotopes that used as tracers, marking a body or a quantity of water. These filed methods allow following the water cycle (rainwater, surface water, groundwater) to be tracked and even a quantitative analysis [56].

Conclusion

The long-term trends can reflect the gradual natural or man induced changes that are occurring in the system over time. A good knowledge of long-term variability of groundwater levels change plays a key role for understanding and monitoring its storage change. Consequently, it is important to apply an integrated management by all of the factors that impact groundwater levels to mitigate constraints and to maintain sustainability.

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