Climate Change and Freshwater Availability: Present and Future Challenges

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ABSTRACT

The interrelationship between freshwater availability with the growing population and climate change estimates is complex. This article investigates climate change role in freshwater resources availability. This is critical issue as freshwater is vital resource for life, and it is in stake as it is depleted worldwide. Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) was discussed. This paper elucidates the climate model downscaling methods used by scholars for future projections. The applications of modelling could provide a holistic approach based on historical data to predict the effect of climate change on the availability of freshwater. However, the people variability uncertainties dominate assessments of freshwater stress, whilst climate change projections uncertainties are more hypothesized to play a smaller role than people.

Keywords: *freshwater availability, climate change, modelling prediction*

INTRODUCTION

Freshwater is a vital requirement for life. It is essential for agriculture, industrial, domestic, and ecological withdrawals. The increase stresses that freshwater experience due to the rapid economic growth, population growth and climate change impacts wide regions in the globe results in considerable ratio of the world population lives under water scarcity [1].Climate changes mainly impact the hydrological cycle which affect freshwater availability by reducing rivers flow and causing drought of shallow wells seasonally [2], human withdraw freshwater at most from terrestrial water [3].

Climate change role in freshwater resources availability was investigated by a figure of studies [4][5][6]. It was concluded that wide regions and more population should face water stress because of the increasing demand influenced by population growth and rise in living standards. However, climate change impact varies regionally with some scholars conclude that climate change impact should influence water stresses [7] although others expect that climate change should decrease water stresses [4]. It can be observed that the foremost methods and studied basins give the dissimilar conclusions.

CLIMATE MODELS AND WATER STRESSES

Many studies indicate the globe water stress due to population growth and increase in freshwater demand without considering the climate change impact in the future estimation scenarios [8][9][10]. A study comparing the impact of population growth and climate change in freshwater resource concluded that for the coming 25 years, climate change impact will be insignificant than the influence of population growth [5].

Climate Models Downscaling Methods

IPCC determines future climate change scenarios under different variables. Global Circulation Models (GCMs) applied to estimate future climate change based in IPCC developed scenarios. The wide modelling grid of 150 km to 300 km gives invalid results that could be straightway used in hydrological models [11]. Therefore, both dynamic and statistic downscaling approaches are applied.

The widely used dynamic downscaling approach is Regional Climate Model (RCMs), which nest within GCMs [12]. RCMs resolution is within the range of 12 km to 50 km with a finite GCMs domain and atmospheric boundary conditions. RCMs consider sub GCM grids scales influenced by land cover heterogeneities and topography features. However, statistical downscaling for RCMs is often required to minimise the inherited deficiencies from GCM.

Statistical downscaling is based on determining the relation between both GCMs/RCMs (large scales) and local climate (small scale) [12]. Advantages of statistical downscaling methods that it is not expensive and applicable to both GCMs and RCMs outputs [13]. Statistical downscaling method is based on main presumption is that a large scale and small scale relation should remain constant in the modelled period, thus increase uncertainties [11].

There are three main statistical downscaling techniques namely stochastic weather generators, weather typing schemes, and regression models [11]. Stochastic weather generators are capable of imitating weather data depending on statistical characteristic variables [14][15]. Weather typing method based on gathering days data into a finite number of distinguishing weather types according to their likeness [13]. Regression models have the ability of quantifying climate variables relations for both small-scale and large-scale atmospheric variables. Weather type frequency is estimated by either GCM or RCM in order to get the projected of climate change [11].

RCMs obtained a wide interest in last years as its ability to estimate climate change is substantially getting better [13]. The improvement in developing a higher resolution RCM output for a climate change in the spatial distribution makes it conceivable to imitate regional climate features like precipitation [11].

IPCC SRES Scenarios

The IPCC SRES published in year 2000, comprise a group of greenhouse gas emission projections until year 2100.

Each projection develop a storyline that characterise the factors that have the major influence on these emissions such as the world economy, population, lifestyle, and political structure. These storylines then assembled as four families, which then develop six SRES marker scenarios [16]. The four families and SRES marker scenarios are as shown in Figure 1 and can be further described as following:

A1: An integrated world with rapid economic growth, increase in wealth with concourse among regions. The source of energy has three assumptions; non-fossil fuel (A1T), fossil fuel (A1FI), and balance upon all energy sources (A1B).

B1: population growth as family A1, environmentally sustainable development with global regulations and cooperation to achieve global solutions for social, economic and environmental stability. A decrease in material intensity and use of more efficient and clean technology.

A2: High population growth and slow economic growth compared to A1, and a more diverse market-led world with regional trends of economic development causing a regional difference in income and technology.

B2: Population growth rate higher than both A1 and B1 but lower than A2, regional solutions for social, economic, and environmental sustainability. The technology is more fragmented than in family A1 and B1.

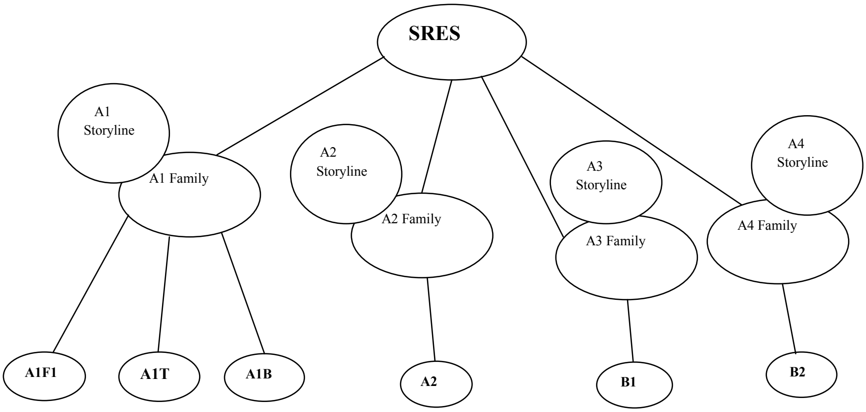

Figure 1: Schematic illustration of SRES scenarios [16]

SRES Temperature and Emission Scenarios

The most climate forcing is under A1 family, followed by the fossil fuel intensive scenario (A1F1) and A2. The fewer climates forcing family is B1 followed by B2 family. Figure 2 demonstrate carbon emission for each marker scenarios, and illustrates the projected rise in globe temperature for each scenario [17].

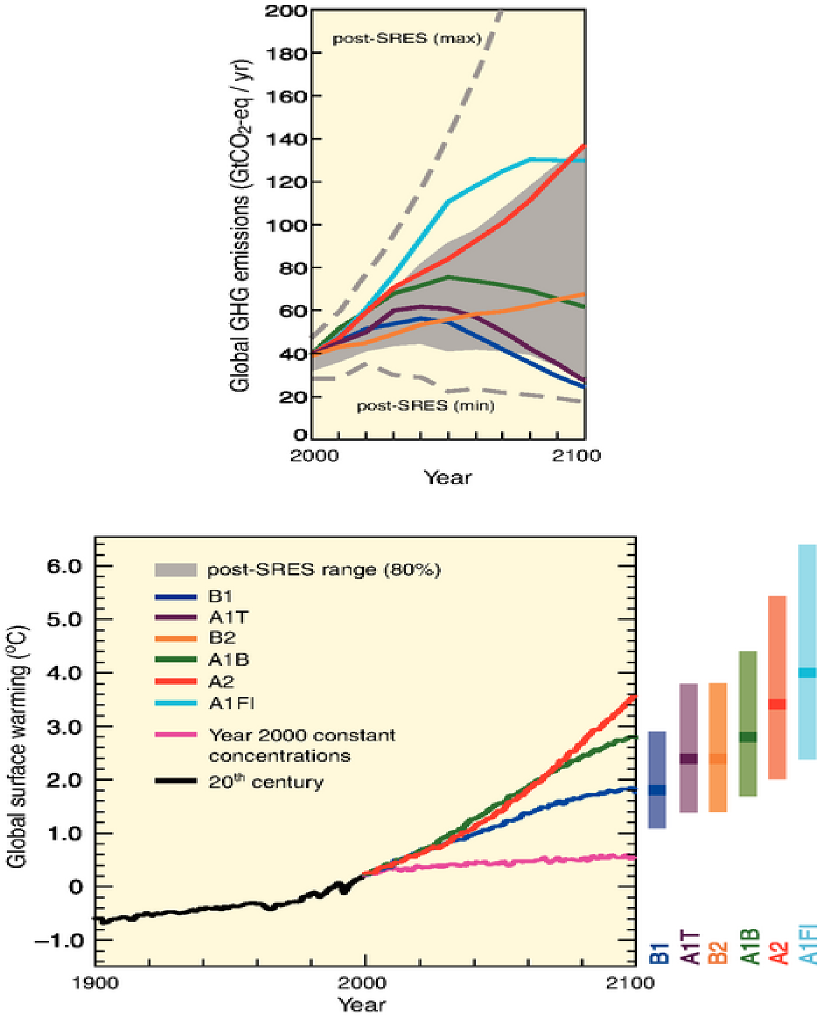

Figure 2: Global emissions and temperature under SRES scenarios [17]

SRES Population Scenarios

The projected global population under the four family scenarios is shown in Table 1. IIASA low fertility and mortality rate projection was applied to both A1 and B1 families, but IIASA high fertility and mortality rate projection was applied to A2 family. United Nations (1998) population projection was applied to B2 family [18].

Table 1: Estimation of Global population in billions

	SRES scenarios families			
Years	**A1**	**B2**	**A2**	**B2**
2025	7.926	7.926	8.714	8.036
2050	8.709	8.709	11.778	9.541
2085	7.914	7.914	14.22	10.235

CLIMATE CHANGE IMPACT ON FRESHWATER AVAILABILITY

The pessimistic studies concluded that more than two-thirds of the globe population would experience severe freshwater scarcity due to the increase stresses [6]; the most significant are climate change and population growth. Water stress is defined as the shortage of adequate freshwater for the multiplicity of its use in the different sectors (domestic, industrial, and agriculture). The main reasons for freshwater stresses are the increasing demand due to population growth and the rainfall variability due to the climate change. World relief agencies (see Table 2) determine 1700 m^3 of freshwater per person per annum as water stress limit and 1000 m^3 per person per annum as severe water stress condition [19]. This widely assumptive concept shown in Table 2 of water stress is based on limitations on food production that caused by freshwater shortage [20]. Almost half of the globe's population (projected around 3.5 billion) would live in regions that experience freshwater stresses by the year 2025 [20]. Mankind main challenge in 21st century is freshwater availability. Water shortage would play a main role in limiting economic development in different regions of the globe. Freshwater quality degradation is a normal consequence of overexploitation of water resource [5] and climate change causing rise in sea level [21], this degradation in quality of freshwater resource further complicate the issue and increase the challenge.

The interrelationship between freshwater availability with increasing population and climate change estimations is complicated. Water availability in year 2025 is estimated to be impacted more by population growth and economic development compared with stresses of climate change [5]. The most vulnerable regions for water stresses are Middle East, North Africa, Central Mexico, and India [22]. However, post the development of the IPCCSRES at year 2000 based on socio-economic projections, a study was carried by utilizing Global Climate Models (GCMs) projections [23]. It was concluded that water stress due to climate change would be experienced on southern Africa, southern Europe, and southern and central United States regions.

Table 2: Freshwater stress classification

Classification	**Freshwater availability (m^3 / capita / annum)**
Unstressed	≥2500
Approaching Stress	<2500
Moderate Stress	<1700
High Stress	<1000
Extreme Stress	<500

Impact of Climate Change on Groundwater Quantity

Climate variability obviously affects groundwater sustainability in terms of quantity and quality of water [10]. Groundwater sustainability impact occurs due to the variability in groundwater recharge rates that affect the depth and the quantity of obtainable fresh groundwater [24]. Although groundwater recharge mechanism is very complex and may vary from region to other [25], the amount of recharge is the main concern for researchers [10]. Furthermore, the change in groundwater pumping pattern effect on aquifers sustainability received less attention from the researchers [10]. The rising in pumping rate for socio-economic development companied with the aquifers replenishment regression due to climate variability, significantly affect the groundwater table [26].

Aquifers characteristics have a main role in its recharge. Small and shallow unconfined aquifers show a high vulnerability to climate change because groundwater replenishment takes place in a meaningful time scale [27]. While large and confined aquifer's response to climate change is slower than small and unconfined aquifers [26]. However, both are vulnerable to groundwater abstraction [26]. Furthermore, the vulnerability of confined aquifers to ground water pumping for human development need is higher due to the aquifer's replenishment process which takes a long time [9]. However, this problem is worsening due to the rise in demand for fresh water and climate change [10].

Recharge rate varies in different region. It depends on precipitation amount, timing and the mechanism of groundwater recharge in semi-arid regions. A heavy magnitude precipitation would results in groundwater recharge. In humid regions, a heavy rainfall result in water lost through runoff that reduces the recharge of groundwater [2].

METHODOLOGY UNCERTAINTIES

Climate change impact on global water resource draws its conclusions from GCMs outputs and hydrology models which have the capability to estimate renewable supplies of freshwater [5][22][28]. Uncertainties from both changes in population and climate need to be considered, and further clarified. The uncertainties on the impact population dominate that of climate change [29]. The population variability uncertainty dominates assessments of freshwater stress, whilst climate change projections uncertainties are more hypothesised to play a smaller role than population. Furthermore, climate changes projection range in scale from multi-decadal up to a century that increase quantification uncertainties due to the climate modelling approaches [30]. Those develop a different viewpoints for the suitable method [31]. The modelling uncertainties developed among serially connected models resulted a cascade of uncertainties that are yet to be solved [29].

To quantify the impacts of climate change on aquifer sustainability, a model should be calibrated with future climate conditions. This enables computation of future climate scenarios that affect the groundwater level. Modelling draws a holistic approach based upon historical data to predict the future climate change effects on groundwater sustainability. However, there is a query on the length of the period that gives a suitable data record that can reliably represent natural climate variability [13]. In reality, uncertainty arises in all stages of the modelling processes that culminate in the future projections.

CONCLUSION

The significant uncertainties that are inherent to future prediction models are still the main challenges. The uncertainties include the precipitation variation, recharge and runoff. Runoff uncertainty is a result of both precipitation and evapotranspiration uncertainties. Further, a significant climate estimation uncertainty is due to the models formulation and timescale.

The impact regional climate change on freshwater resources studies that account for both regional and global human impacts need to be carried out more. The knowledge should increase the planning analysis and further the mitigation aims in overcoming climate change consequences on freshwater resources. However, this knowledge is accumulating to minimise the uncertainties and develop more precise approaches in the future.

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