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Analysis of water diversion regime from projects of inter-basin water transfer based on pattern and continuity of precipitations

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Abstract

Integrated management of water resources and consumptions are from the primary principles of stable development in a basin. There are comprehensive models of water management in many countries and these models have been implemented for optimal using of water and soil and other resources in maximum mode. On the other hand basin management without management on its branches and fountainheads is meaningless. In this paper was investigated branches of Karun and Zayandehrud basins by analysis of water diversion regime that done by Koohrang-I and II tunnels. These tunnels are in an inter-basin water transfer (IBWT) project. IBWT, in which water is transmitted from a basin with high water availability to a neighbor basin with high water use, has been proposed as a solution to water scarcity. Relationships between precipitation type with diversion water volume by these tunnels dams and between amount of annual rainfall and snow with water transfer of tunnels was investigated in a statistical period (1999–2014). Results showed air temperature has an increasing trend, and mean temperature (tmean) has increased about 1.2oC during of the under reviewed period. Comparison of rain and snow water graphs shows type changing of precipitations from snow to rain in this period. Also due to the air warming and snowfall decreasing, it is possible to justify the decrease of the water transfer of tunnels (about 43% decreases). Results show that snow water or the same snowfall has a more effect on water transfer of tunnels than rainfall. Therefore, snowfall changes are more important in this field. Analysis shows the uncertainty and unreliability to the performance of IBWT due to the precipitation type changes (from snow to rain) and the diversion of water amount in the Koohrang tunnels. The comparison of the expected diversion volume of water by the tunnels with the observed discharges of these tunnels indicates that this expectation has not been met and there is up to 90% discharge reduction in some years that differences with design capacity, which shows IBWT project between Karun and Zayandehrud basins has not been able to meet the goals. This topic is an uncertainty in IBWT project.

Highlights

• This study examines water storage management in arid regions where water is transferred between areas.

• It aims to provide guidelines for sustainable water resource management and risk control in inter-basin water diversion projects.

• The research emphasizes the impact of climate change on regional runoff processes and the necessity of adapting to changing conditions.

• Findings highlight the influence of inter-basin water transfer on the water cycle, patterns, and ecosystem functions, emphasizing the importance of monitoring eco-hydrological changes for future water management policies and sustainable development.

Introduction

In different regions of the world, non-uniform distribution of precipitation (e.g. in Iran from 2000 mm in the Zagros Mountains to 50 mm and less in the southern, eastern and central desert regions) is very high in different seasons and parts (Domroes et al, 1998; Dinpashoh et al, 2004; Ashraf et al, 2013). Located in an arid and semi-arid region of the world, Iran has experienced many extreme flood and drought events in the last and current century (Modarres et al, 2016). In recent years, the uneven distribution of water demand and resources has created challenges that caused increasing in the inter-basin water transfer (IBWT) projects from an adequately watered basin to another watershed faced with scarcity of water to eliminate pressure of water supply and creating of economic growth and balance (Sadegh et al, 2010). Big environmental changes make it harder to understand how to share water fairly. Poor water-sharing decisions can lead to more competition among users, creating big problems for managing water resources in projects that transfer water between different areas (Zhang et al., 2024). The concept of the interlinking of rivers (i.e. IBWT) is one of the best ways to achieve the regular distribution of surface water in India and will also deliver economic and ecological benefits for sustainable development (Shah et al. 2006). However, the IBWT projects have changed the natural inflows and events. Thus, there is a need to update the previous operating rule for better efficiency of these projects and less damage to the environment (Xi et al, 2010; Guo et al, 2012; Zhu et al, 2013; Zeng et al, 2014). In an IBWT system, the first main purpose is providing of water users needs without violation of system constraints. IBWT is a project to create uniformity in water resources and economic conditions in a country. But there are heavy costs, including energy costs for pumping stations and large construction projects (Peng et al, 2015). To deal with the increasing need for water and the uncertainty of supply because of climate change, many cities worldwide have invested in IBWT. IBWTs can help make sure that there is enough water in the right places at the right times. To make IBWTs more dependable, they are connected to water storage places like reservoirs. Having more water and better ways to use it can help make sure everyone has enough water, even in places where there's not a lot of rain. Also, the programs that manage water resources now and in the future rely on storing water on the surface, which can be greatly impacted by changes in rainfall. This problem was looked into in Kenya in Africa and the result was that. The government should make a plan for how to manage water resources. This plan should include both developing new sources of water and finding ways to use less water. One way to make sure there is enough water for people who live in Kenya is to use different ways of collecting and reusing water, like capturing rainwater, using groundwater carefully, and reusing wastewater. This can help make sure there is enough water for people who live in cities (Nyingi et al, 2023). The results showed that IBTs help slow down the decrease in groundwater levels and increase the amount of water stored each year. These projects also helped to increase river flow, add more water storage, and make up for water loss from evaporation and plant use. IBTs also greatly change the seasonal ups and downs and timing of river and groundwater flows. More water helps plants grow back and creates different time periods for plant growth, ranging from monthly to yearly (Wang et al., 2024). Studies on IBWT in southern and central Africa have shown that it can have a big impact on the environment. This includes things like changing the land, bringing in new plants and animals, mixing genes of different species, and affecting the quality of the water. It can also change the

climate and spread diseases. So, it's important to have really good plans and ways of doing this, even on an international level, to understand how it will affect the environment and the people living there (Davies et al, 1992). Connection of two or more basins that not connected previously by the IBWT enables water management on a larger scale (Gupta and Zaag, 2008). Due to the importance of water management in IBWT with regard to water supply and demand issues, detailed engineering and environmental studies should be used in the implementation of these projects (Neelakantan and Pundarikanthan, 1999). There are regulations for water transfer by IBWT, including that water transfer should be begin when the destination basin needs water and the source basin has more water than it's all social, environmental and ... needs. Therefore, the mentioned laws must be in line with the weather conditions (drought,) and supply and demand in each basin (Zeng et al, 2014). Presenting an integrated model with critical considerations such as social, political, environmental, technical, and economic can serve as a useful and practical model in water resources management in IBWT projects (Roozbahani, and Ghanian., 2024). IBWT also affects the life of the organisms in the basin due to effect on the physical, chemical and biotic attributes of the rivers (Snaddon, 2000). IBWT and taking water out of the water systems in the area make it hard for animals to move around. It also makes the estuary have less water flowing into it and changes the way lakes look and what's in them. This has a big effect on the animals that live in the water. The results of IBWT show that the whole coastal ecosystem, from the ocean to the rivers and lakes, is messed up because animals can't move like they used to (Cyrus, 2001). Therefore, in IBWT projects, with proper management in the watershed and proper agriculture and river protection, living organisms can be protected and the flow of rivers should be maintained in such a way that the current habitat diversity is maintained (to prevent any disturbance in their natural growth cycle) and a sufficient and minimal flow pattern in the source basin. Therefore, water release must be managed properly and comprehensively (Viljoen and Cyrus, 2003). Drought causes water problems, imbalances in supply and demand, and economic and social problems (Pai et al. 2010). Some of the rules governing the IBWT are multilateral decisions with important objectives such as maximum water supply while minimizing water transfer (Peng et al, 2015). At the present time, due to implementation costs and capital constraints for IBWT projects, these projects funding are faced with serious challenges and even made impossible. The economic analysis of these projects for the proper decision making needs to consider of the hydrological conditions and possible risks. The first consideration is determination of reliable capacity for water transfer and uncertainties knowing related to these projects, and the second consideration is economic comparison of these projects with others such as sweetening water, wastewater treatment (recovery) and aquifers reviving (with artificial nutrition) and management of consumption and savings. Safe or reliable capacity in the management law of water supply refers to the capacity of water supply from surface or underground resources without adverse effects. That which should be reliable is water amount that can be diverted from origin source or resources in this field. Reliable capacity and performance is depends on conditions consistent and continuity in availability of system's capacity that is expected, that shows the need to future predict including repeated droughts in the useful life of the IBWT projects. It must be ensured that the water resources are reliable enough. Reliability of resources depends on the diversion origin and other system characteristics. The pattern of hydrological changes and changes in the pattern and amount of consumptions should be considered to determine of reliable

capacity, and this water amount must be achievable continuously without undesirable effects on the other sections (environmental flow, upstream, downstream). There are uncertainties to determine of reliable capacity. The first and most important source of these uncertainties is the fundamental differences in the global climate models that used to future prediction. The second main source of uncertainty is the converting process of these models output through hydrological models to extract the planning parameters in these studies, that these hydrological models have same uncertainties. No model is capable for natural phenomena simulating by its equations and computational structure completely and there is an error in every prediction. Because of these factors, researchers say the era of large IBWT development is about to end, at least in democratic developed countries (Rinaudo and Barraqué, 2015; Niekerk and Plessis, 2013). Reliability, flexibility and vulnerability are the main pillars of a system (Kjeldsen and Rosbjerg, 2004; Asefa et al, 2014). For future planning of a system or project, there are tools that express the certainty and uncertainty of achieving project goals, and thus can be planned for these (Dong et al, 2013). One of these uncertainties is in IBWT projects, because the factors affecting them are dynamic conditions such as rainfall and runoff and etc. This uncertainty is also exacerbated by the development of human societies and the greater need for water. (Zuo et al, 2003). IBWT governance models based on rainfall forecast information improve water resource management compared to other models (Shu Feng et al, 2010). The IBWT project is implemented according to the coordination and supply of needs in the source basin and then the amount of shortage in the destination basin. Due to the uncertainty of the factors affecting water supply in the source basin such as rain and snow and the distribution of rainfall, the amount of water transferred that is continuous and with a specific flow and has the ability to be considered as IBWT capacity is considered (Shao, 2001 and Shu Feng et al, 2010). Tools and software based on intelligent water allocation such as genetic algorithms can improve performance of IBWT (Zhou et al, 2017). These tools can be used to manage and use IBWT by making continuous decisions on flood control and water supply, which is the main purpose of these projects (Shu Feng et al, 2010). Water management rules must improve to enhance irrigation efficiency and protect groundwater (Raeisi Vanani et al, 2017; Safavi et al, 2015). IBWT projects must transfer water within designed capacity to avoid environmental impacts. Prioritize water for industry, environment, and consumption before transfers (Peng et al, 2015). In some researches, has been used variables simulation to make better decisions for future planning to allocate environmental demand and the least impacts on groundwater based on climate and consumption changes for IBWT capacity design (Shourian et al, 2017). The research on how dependable water transfer is between different areas in various weather conditions found that it was least reliable in dry years, more reliable in normal years, and most reliable in wet years. This means that these projects do not meet their goals in dry and normal years (Nyingi et al., 2024). Today, balancing between supply and demand is important in integrated water resources management with the approach of sustainability (Ludwig et al, 2014; Molinos-Senante et al, 2014; Dukhovny, 2004). For this purpose, tools and techniques should be provided in accordance with the conditions of each basin (Xie, 2006). Climate change is causing the problem in this purpose (IPCC, 2007). Climate change is caused by human and natural factors that negatively affect water resources (Kumar and Verma, 2020). The sensitivity of water resources relation to the climate change phenomenon showed in different parts of the world that the Middle East region is among the critical areas (Alcamo et

al, 2002). Investigation of climate change effect in Lebanon basins showed that if temperature increases 2^{o}C then runoff peak discharge occur two months earlier (Hreiche et al, 2007). Climate change affects snow runoff time and it does not affect its amount (Jain et al, 2010). Climate change has changed the amount and type of rainfall, which plays a significant role in the water resources management (Clark et al, 1999). Precipitation depends on many dynamic physical factors (Roushangar and Alizadeh, 2017). Investigating the trend of temperature indexes in Iran climate in 1951–2003 showed that indexes like frosty days, cold days, cold nights and nightly temperature changes have a decreasing trend and indexes such as summer days, hot days and hot nights have an increasing trend (Rahimzadeh et al, 2008). Reducing of the precipitation will effect on water quality (TDS, EC and Na and other parameters) in rivers and this is dangerous environmentally (Mohsenifar et al, 2010). The joint management of water resources at the international level is also very important because, for example, this issue in the development of South African society and it has contributed to regional integration, socio-economic development and poverty reduction. Protocols have come into force in this field, which aim to foster closer cooperation between countries and coordinated management (Heyns et al, 2008). Regional water transfer is one of the tools to deal with water shortage, which has challenges such as social desirability, which is as important as the technical and economic feasibility of such projects. In some areas, due to factors such as regional imbalance and migration as a result of water shortage and the lack of suitable alternative options such as rainwater harvesting instead of water transfer, the government has no choice but to implement water transfer projects (Gupta, 2001). The effects of IBWT on watershed hydrologic balance and related ecosystem processes in arid regions are poorly understood due to a lack of data and the complexity of ecosystem responses to water management in many parts of the world. So with regards to considered issues and problems such as climate changes, drought, precipitation type changes and water problems in the Karun basin and IBWT between Karun and Zayandehrud basins by the Koohrang-I and II tunnels, in this paper analyzes water diversion regime from Karun branches based on pattern and continuity of precipitation.

Materials and Methods

Iran has diverse climate and weather conditions, including mild/humid, warm/dry, cold mountain areas, and warm/humid regions with varied types of precipitation. The Zayandehrud river in the central Kavir desert is the country's only permanent river, making its basin vital for irrigation, industries, animal farming, and municipal water supply (Safavi and Alijanian, 2010). That's while more than 90% of its water resources are from Zagros Mountains (Murray-Rast et al, 2000; Raziei et al, 2008) in Chaharmahal and Bakhtiari province. The civil project Koohrang-I,II tunnels transfer water from Karun to Zayandehrud basin. Koohrang-I, operational since 1953, consists of a dam and a 2900-meter tunnel, conveying 340 MCM annually to Zayandehrud basin (IWRM in Isfahan, 2014). Koohrang-II tunnel system used in 1986 transfers 250 MCM water to Zayandehrud basin annually. Please feel free to ask any questions (Gohari et al, 2013). Also, Koohrang-III tunnel, 23 km long, not yet open, built to transport water from Birgan to Zayandehrud basin (Zayandab Consulting Engineers, 2005; Ajalloeian et al, 2016).

Geographical coordinates of I and II tunnels in the zone 39S are X = 415336, Y = 3589639 for inlet and X = 417722, Y = 3591206 for outlet of firs tunnel and X = 417945, Y = 3586187 for inlet and X = 419471, Y = 3589683 for outlet of II tunnel. The aerial and topography maps of these tunnels were shown at Fig. 1. Water transfer technique is gravity flow form Karun to Zayandehrud basins by these tunnels whit diversion dam (Fig. 2).

The climate in the Karun basin and its launches in Chaharmahal and Bakhtiari province is cold and mountainous. Weather data was collected for analyzing precipitation levels, flow discharge in tunnels, and weather patterns. Data was sourced from Isfahan regional water board and the province's weather office, covering precipitation, tunnel discharge, and weather indexes. Hydrometric and weather stations in the Koohrang basin were utilized for the study, highlighting data challenges in hydrological projects (Safavi et al, 2015) such as this research. Data are includes of precipitation type, amount of annual rainfall and snow, snow water, tunnels discharge, air temperature (t_{min}, t_{max} and t_{mean}), height snow, number of freezing days, number of days with precipitation, average of relative humidity, average of maximum air pressure ((Air Pressure) $_{max}$) and sunshine hours that was used in a statistical period from these stations (1999–2014) and also regression was established between different data. Among these data air temperature, snow amount and snow water are important because are from highlight characteristics of hydrological in mountainous areas that can be one of the major concerns for water managers (Biggs and Whitaker, 2012). Some research has been done on snowmelt runoff, and by using rainfall, temperature and snowmelt, models have been defined to simulate flow in basins (Lorrai and Sechi, 1995; Tokar and Johnson, 1999; Miller et al, 2003; Stewart et al, 2004; Payne et al, 2004). Runoff from snowmelt simulates using the snow cover surface by satellite images (Li and Williams, 2008; Nabi et al, 2011; Franz and Karsten, 2013). Snowmelt runoff also estimates using remote sensing (Jain et al, 2010). Snow cover and volume of snow water provide about one third of the water needed to irrigation and agricultural products the entire world. Snowmelt runoff is a very important water source in most areas (Goodinson et al, 2000). Scientific research on snow faces challenges like dynamic changes in snow mass from water infiltration during snowmelt. Snowmelt water can refreeze, hindering future infiltration. Rising temperatures exacerbate water losses through evaporation. To understand snowmelt flow, timing is crucial to study discharge relationships (Colbeck, 1996). In simulating of climate fluctuations, data average uses in the long-term periodicity in calculations instead of using data directly (Jones and Hulme, 1996). Relationships between parameters in this paper were investigated and were used statistical tests to determine of relationships significance at 1% and 5% levels.

Results and Discussion

Annual precipitation (Rain + Snow) of this basin varies from 733 mm to 1959 mm, of which about 83–97% (706–1764) of the total amount occurs in the wet season staring from November to April and 3–17% (27–237 mm) in other months in 1999-2014s. Based on data obtained from the regional Meteorological and Water Administration, a graph was drawn between the snow height and its equivalent water content. Then, by drawing a linear trend between these two data in this graph, a

mathematical relationship between these two parameters was obtained. The relationship between snow height and snow water was also studied and charts was obtained as following:

As can be seen in Fig. 3, there is a linear relationship between these parameters with about R- squared value of 0.84. Relationships between parameters were investigated by following charts. Given the direct relationship between meteorological parameters and the amount of water supply for transportation by tunnels, which is the amount of snow and rainfall in the region, it was necessary to examine the relationship between these parameters, such as air temperature, rainfall, sunshine hours, etc., and the flow rate of the tunnels, and these relationships are explained below each figure.

Water transfer is an important evaluation index for IBWT projects. Relationship between other parameters with water transfer of tunnels (Fig. 4) shows more correlation between water transfer of tunnels and mean temperature of air (t_{mean}), precipitation and sunshine hours. Also, results show that snow water or the same snowfall has a more effect on water transfer of tunnels than rainfall, because R-squared value for Snow water-Water transfer chart is more than Rain-Water transfer chart. Therefore, snowfall changes are more important in this field.

The Fig. 5 shows that there is a good correlation between t_{mean} with relative humidity, number of freezing days, number of sunshine hours, with a R-squared of about 0.8. The correlation coefficient between t_{mean} and snow water is higher than rain that shows temperature changes affect snowfall more than rainfall; also, climate change with average temperature index affects more snow (snow water) than rain. Increasing the t_{mean} has reduced precipitation, especially snow.

According to the Fig. 6, air temperature has an increasing trend, and mean temperature (t_{mean}) has increased about 1.2^{o}C during of the under review period. The number of freezing days has also a decreasing trend that can be said it is due to the air warming. Comparison of rain and snow water graphs shows type changing of precipitations from snow to rain, and also intensity of decreasing trend for snowfall changes is more than intensity of increasing trend for rainfall changes. Also due to the air warming and snowfall decreasing, it is possible to justify the decrease of the water transfer of tunnels (about 43% decreases). The comparison of the expected diversion volume of water by the tunnels (IWRM in Isfahan, 2014; Gohari et al, 2013; Zayandab Consulting Engineers, 2005; Ajalloeian et al, 2016) with the observed discharges (Fig. 6 and Fig. 7) of these tunnels, indicates that this expectation has not been met and there is up to 90% discharge reduction in some years that differences with design capacity, which shows IBWT project between Karun and Zayandehrud basins has not been able to meet the goals. This topic is an uncertainty in IBWT project. Also, the volume transfer chart is more similar to the snow chart in years, and this shows the greater effect of snow on the water diversion from the tones in Fig. 6, both have also descending trend with almost the same R-squared of about 0.4. Therefore, relationship between the volumes of water transferred by the tunnels with snowfall was more investigated.

Relationship between water transferred and snow water (snow) was investigated to determine the lag time in discharge creation by snowfall. The results showed that there was no relationship in this case, but snow water has a direct relationship with water transferred in the same year. Figure 7 show maximum water transfer of tunnel-I,II is in 2003 and its minimum is in 2007, so the charts of cumulative precipitation and cumulative water transferred were drawn in 2003, 2007 further researches in Fig. 8. The amount of water transferred was about 175 MCM more than the design capacity in 2003, but there is a deficit of about 500 MCM rather than the design capacity in 2007 that shows there is a big difference between the maximum and minimum in the study period. The climate changes could be the cause of this event. The reliability of water supply can be described by the probability that a water supply system remains in a satisfactory state (Zhou et al, 2017) therefore according to Fig. 7 reliability of water supply in this research isn't satisfactory in 80% of cases. In a similar study, an uncertainty assessment of IBWT in South Africa showed that transmissions were significantly lower and more variable than predicted (Van Niekerk and Du Plessis, 2013).

Figure 9 shows relationship between Snow water ratio to total precipitation with Transfer volume ratio to the design volume.

In spite of objectives of Koohrang-I and II tunnels building in IBWT for transmission of a certain water volume and in view of the precipitation type changes, these objectives were not met and there is an uncertainty in this field that is significance at 5% levels. Investigations of reliability, vulnerability and resilience in IBWT projects should be considered at the same times that are as the appropriate criteria for evaluating and improving IBWT projects. IBWT project, because it reduces the downstream flow of the basin, can increase the vulnerability of these projects; due to imbalance of the water demands between water transfer projects and socio-economic-environmental sectors, etce. So we have to look for projects that will improve the reliability, vulnerability and resilience of water supply. The results indicate that the changes in vulnerability and resilience are more significant than those of reliability according to the radar maps, and thus the vulnerability and resilience are more sensitive to water transfer projects than the reliability (Zhou et al, 2017). Studies show that the water diversion plan works well to help communities become more resilient. However, there are still ways to make the plan even better. Also, when the water supply and demand situation is worse, there are more opportunities to improve how sustainable the system is. The current IWBT studies can help us learn how redirecting water affects the long-term health of our water resources in a changing environment. Improving the way we distribute water can make the water system much more sustainable (up to 0. 99) even with changes in climate and economic growth. Also, when water is harder to find and there is more demand for it, making the allocation plan better can lead to bigger improvements (Chen et al., 2025). This study can help create guidelines for managing water storage in projects that move water from one area to another in dry regions. For example, the results show that how we manage water in reservoirs can lower the amount of water moved and reduce costs, while still making sure there is enough water available. This study gives important information to help leaders manage water resources in a sustainable way in this area (Roque and de Medeiros., 2025). A good system can help manage water use wisely and support leaders in making decisions during times of water shortages. These frameworks are designed to use water

resources wisely in IWBT projects. They help decision-makers create the best plans for sharing water as environmental conditions change. This way, we can lessen water shortages and competition between regions, supporting sustainable development in those areas (Zhang et al., 2024). This paper looks at how climate conditions have changed over time and what other studies have found. It shows that changes in the climate in the future will affect how water flows in different areas. This could create big problems for projects that move water from one basin to another (Mu et al., 2024). This research is very useful for managing risks in water transfer projects between different areas and for ensuring safe water supply in regions. The findings from this paper and other studies show that to keep the basin's water resources usable for a long time, we need to create plans that improve how we use water and recycle it. We should also combine these efforts with other sources of renewable energy (da Encarnação Paiva et al., 2024). This paper aims to assess and improve the advantages of moving water between different river basins. The results show that plans for sharing water should consider water needs, money, and nature in the area that receives it. This is important because how we share water can influence the balance between making money and protecting the environment. By using the models, a better way to move and share water can be chosen based on different needs, and all measures can be greatly improved compared to the usual plan. Our study can help tackle the problems related to IBWT projects. It can also guide economic growth in the areas that receive the water, while making sure water transfer and use are done efficiently (Jia et., 2024). Our findings show that IBWT has changed the water cycle, water patterns, and ecosystem functions in the area we studied. We need to keep a close watch on how often and how much eco-hydrological changes happen from IBWT. This information is important for creating good water management policies that will help us develop sustainably in areas that don’t have enough water.

Conclusions

Many Inter-Basin Water Transfer (IBWT) projects fall short in delivering the intended water volumes to target communities due to uncertainties in determining reliable capacity. Cost analysis based on providing a specific water volume per year and price per unit lacks realism. Successful management of IBWT projects requires considering various criteria, such as engineering, social, economic, and environmental aspects, in both source and destination basins. Simply meeting short-term goals like compensating for water deficits doesn't guarantee project success in addressing hydrological issues. Please summarize this text and include the main points in about 4-5 sentences (Yeh 1992; Wagner 1995; Singh, 2014). Long-term planning in water projects like IBWT should consider all aspects for success (Kumar and Verma, 2020). Among the problems in water transfer projects is the drying of springs and groundwater during these projects (Zayandab Consulting Engineers, 2011). Therefore, to prevent these problems, the previous water laws must be amended (Shourian et al, 2017). Ongoing need for detailed IBWT water allocation research with advanced technology for development is necessary (Zhou et al, 2017). The research highlighted the impact of changing weather conditions on water resource management in origin basins. It suggested that for Inter-Basin Water Transfer (IBWT) projects, creating new dams or diversions to manage uncertainties and climate change could be considered. However, due to high costs and uncertainties, alternative options should be explored. River-linking was proposed as a

comprehensive solution to match IBWT projects with new weather conditions by balancing supply and demand, addressing environmental, social, and economic concerns, and improving water management. It emphasized the need for river-linking to address water deficits in basins. Generate a question based on the summary provided (Kumar and Verma, 2020). Creating a database network, national water policy, and awareness programs involving beneficiaries like farmers can optimize water use in the new climate. Implementing new techniques and strategies in Zayandehrud basin can enhance water quality and promote recycling. Flood water transfer can follow after meeting river basin needs. The results of this study show that a combined method can help decision-makers and interested parties assess water transfer projects between different areas. The results of this study show that an integrated approach can help decision-makers and stakeholders in evaluating inter-basin water transfer projects. It is also suggested that under different scenarios, the most optimal inter-basin water transfer project in different regions should be selected and implemented to provide water in each basin, taking into account environmental, social and economic, challenges to provide useful insights for policymakers in the field of water management.

Declarations

FOR COI STATEMENT:

Author's Contributions:

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Kaveh Ostad-Ali-Askari], [Hamid Raeisi Vanani] and [Peiman Kianmehr]. The first draft of the manuscript was written by [Kaveh Ostad-Ali-Askari] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Availability of Data and Materials:

Some or all data, models, or code generated or used during the study are available from the corresponding author by request.

Conflict of Interest:

There is no conflict of interest.

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Ethical Approval:

The present study and ethical aspect was approved by Water Engineering Department,

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Consent to Participate:

All authors designed the study, collected data, wrote the manuscript and revised it.

Consent to Publish:

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Figures

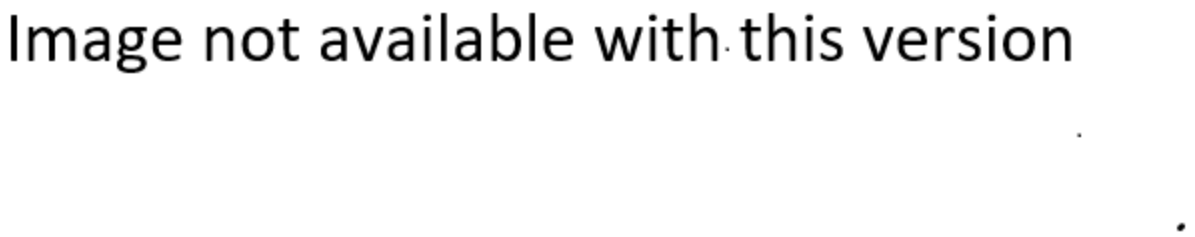


Figure 1

Location and general schematic of the Iran basins, Koohrang-I, II tunnels



Figure 2

Diversion dam and tunnel inlet

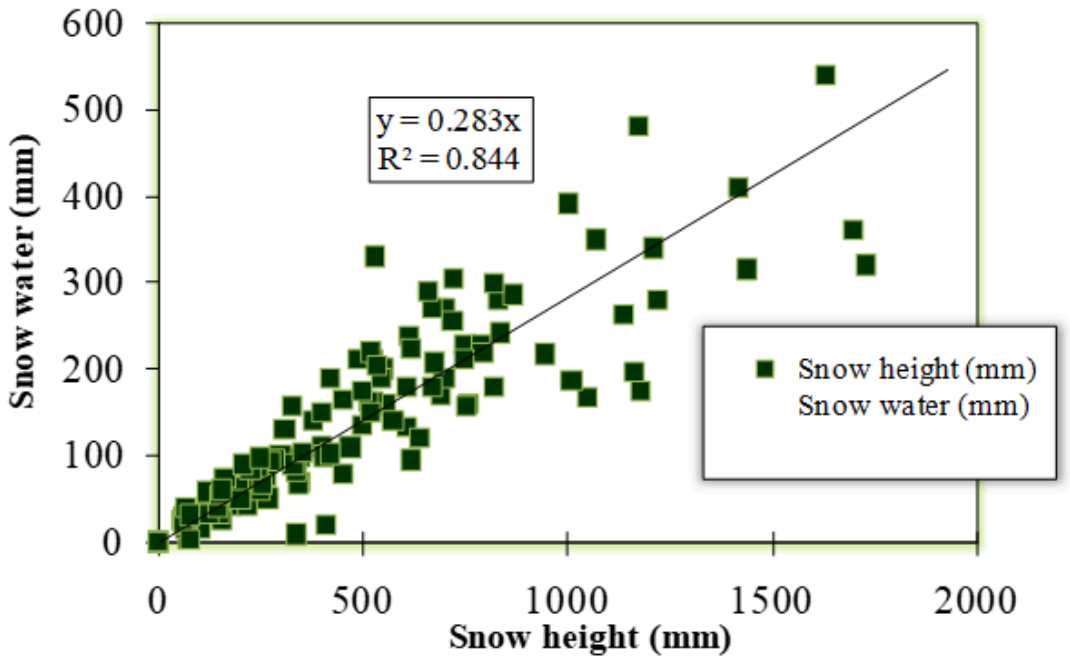


Figure 3

Relationship between snow height and snow water

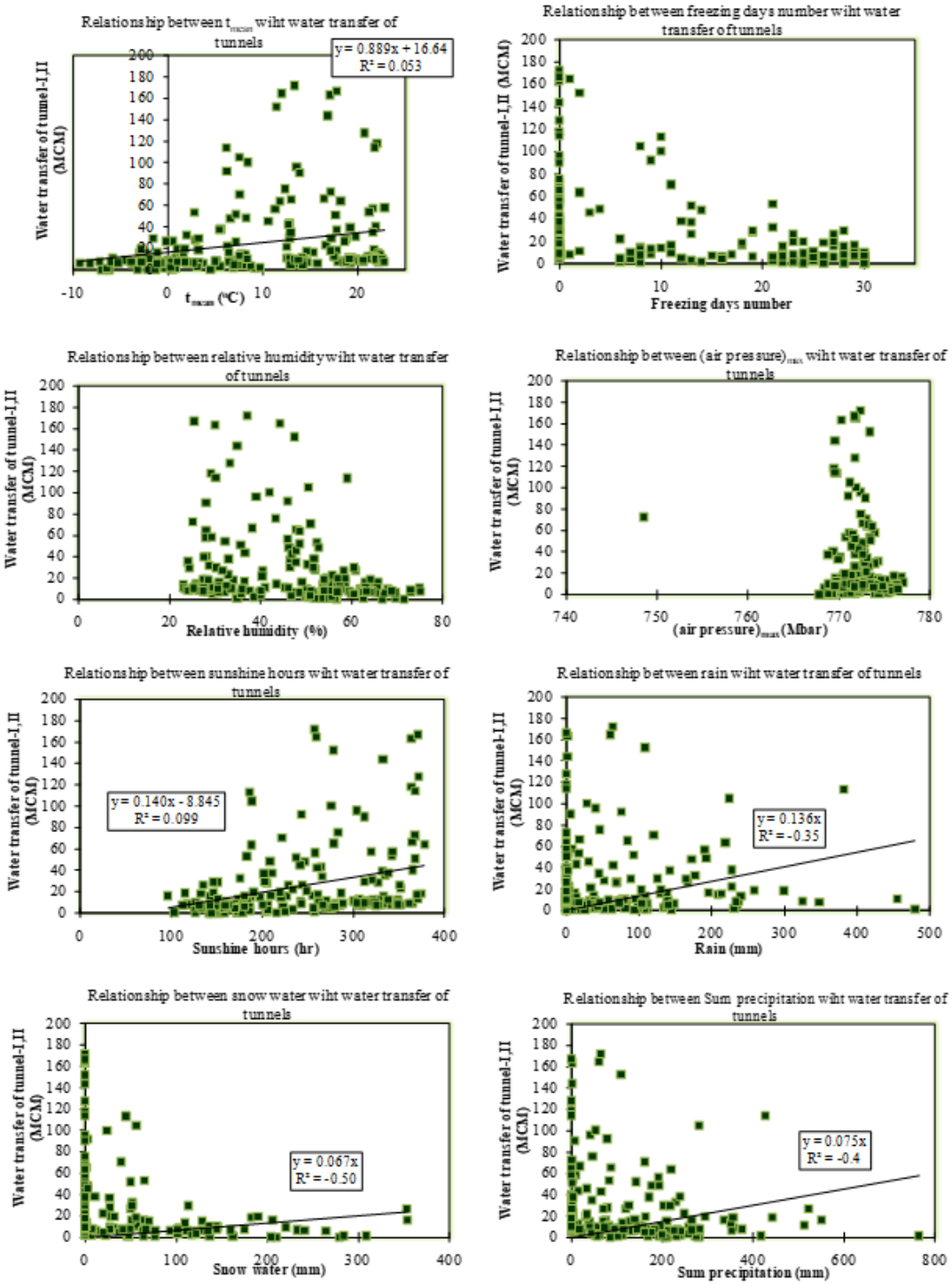


Figure 4

Relationship between parameters and water transfer of tunnels

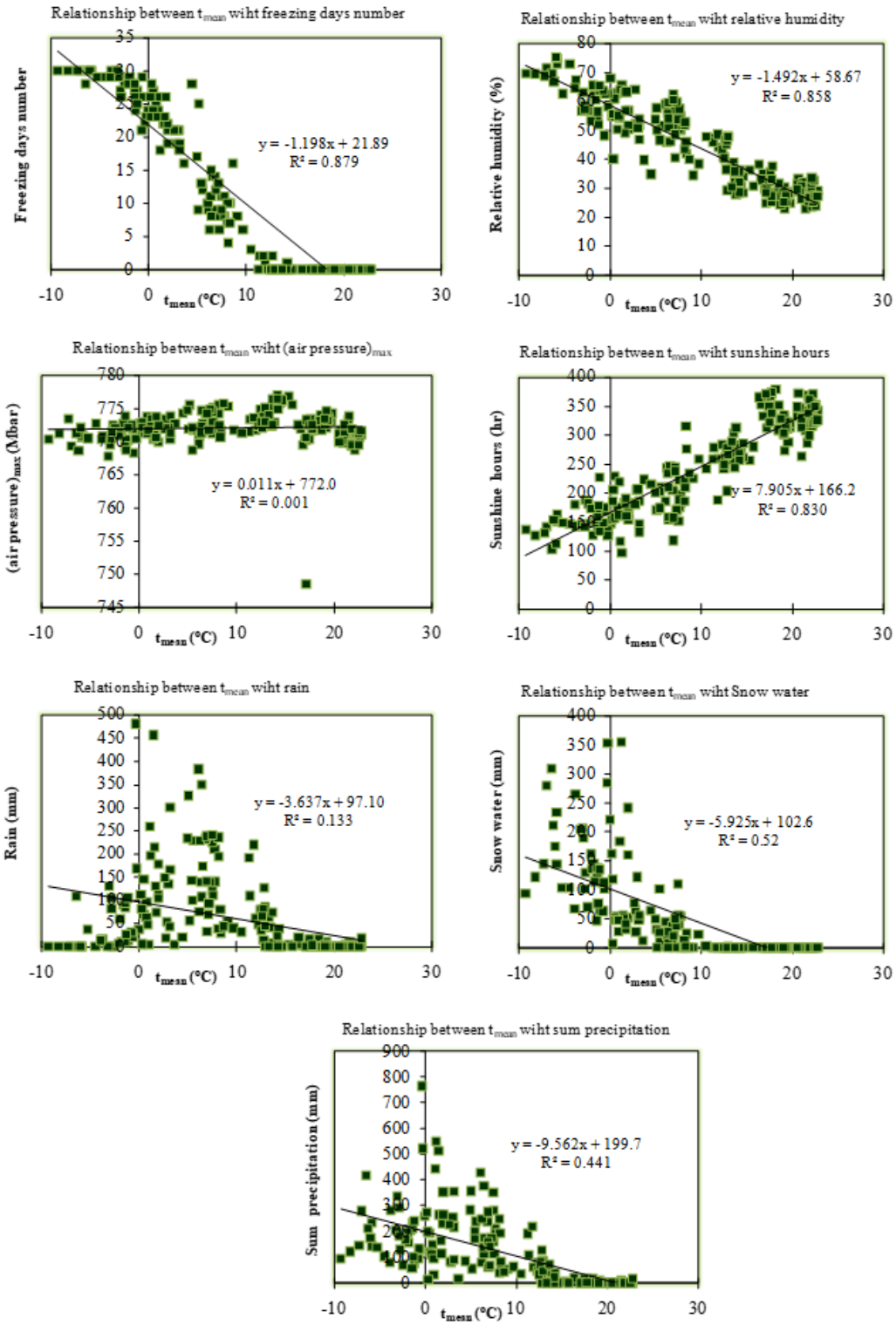


Figure 5

Relationship between t_{mean} with other parameters

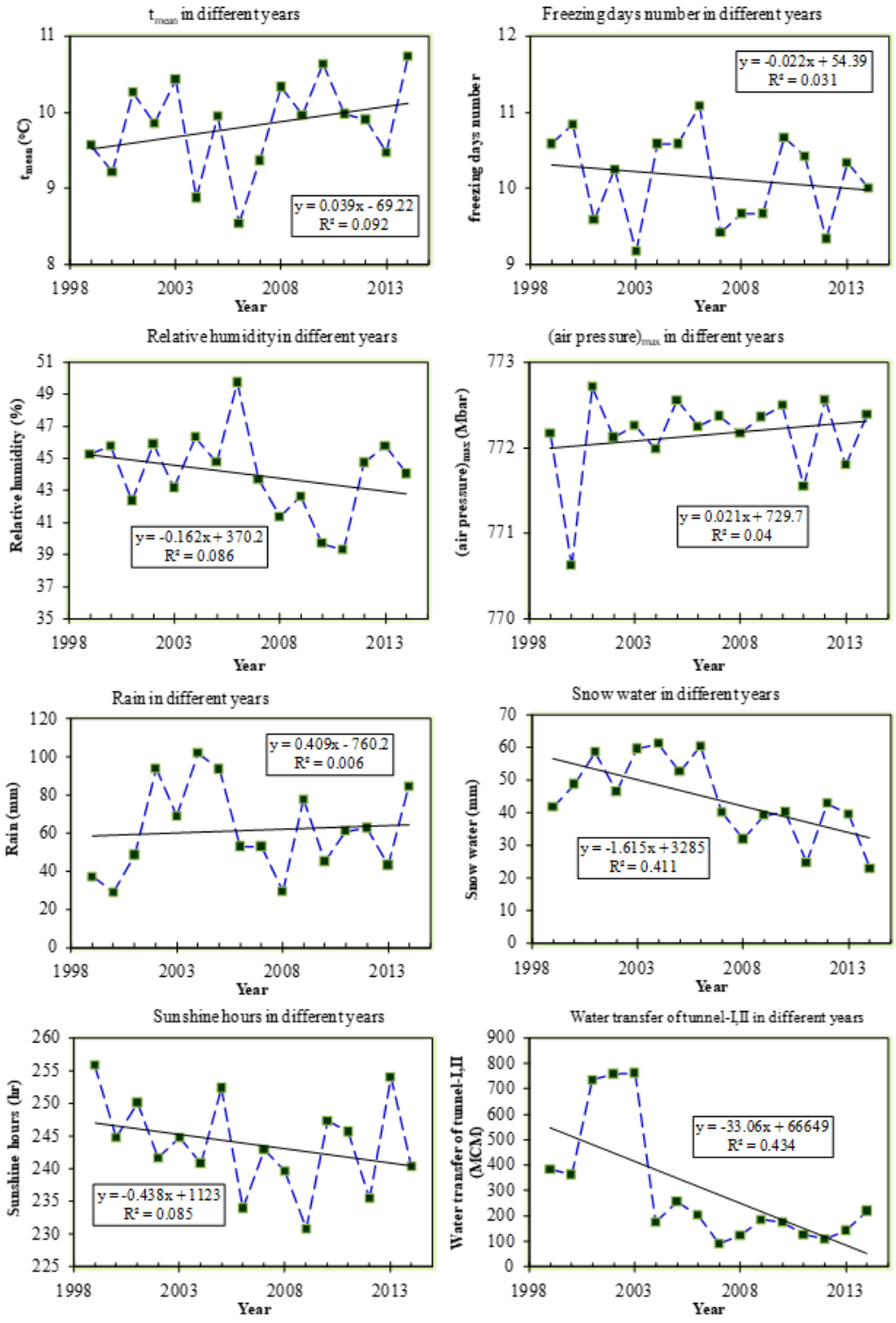


Figure 6

Mean of the parameters and changes trend in different years

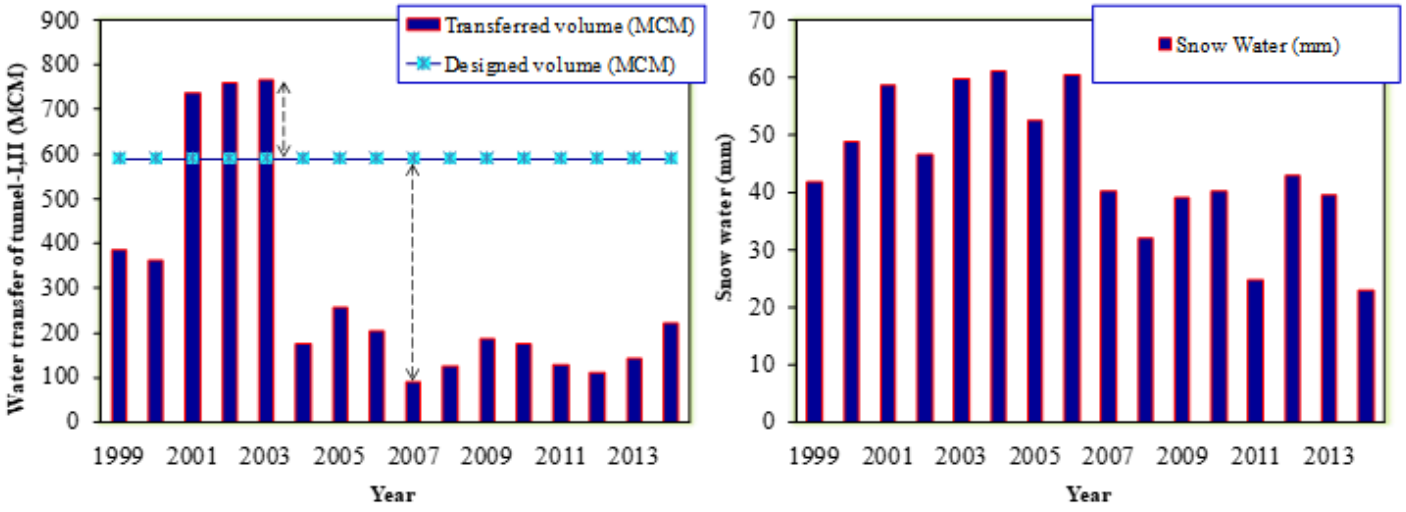


Figure 7

Water transferred and designed for Koohrang I-II tunnels and snow water in study period.

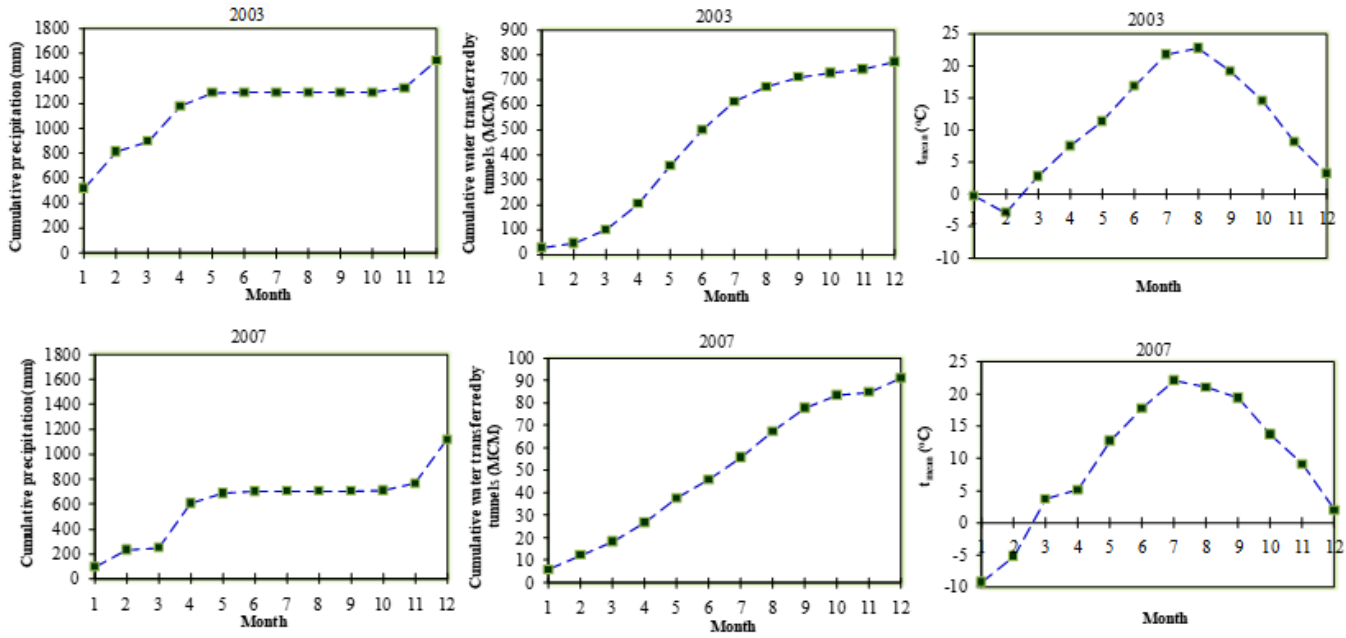


Figure 8

Cumulative precipitation, cumulative water transferred and t_{mean} in 2003, 2007

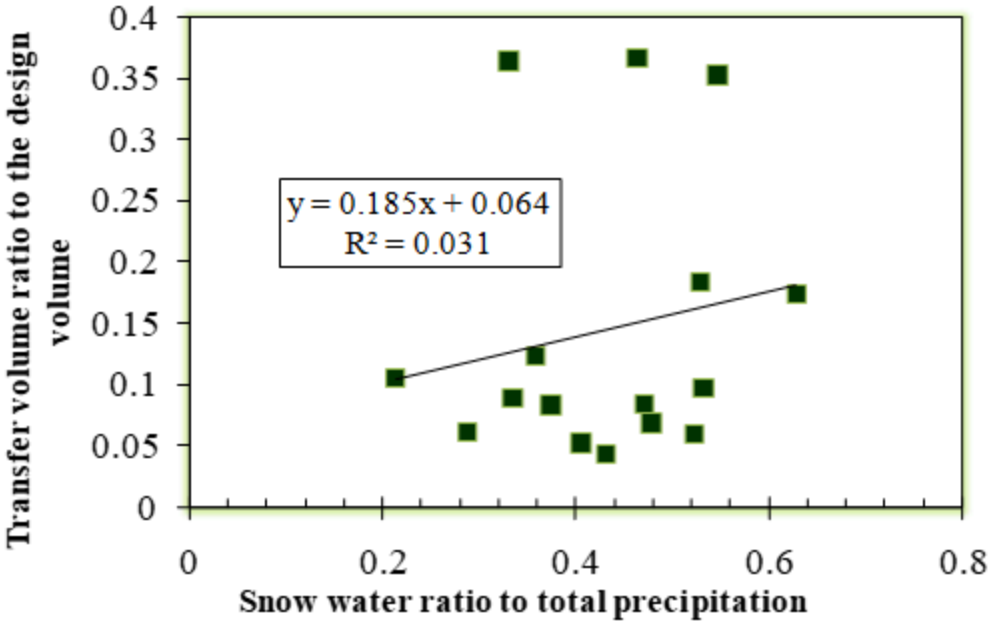


Figure 9

Relationship between Snow water ratio to total precipitation with Transfer volume ratio to the design volume