Hydrologic Response of North Karun Basin to Increase in Minimum Air Temperature

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Extended Abstract

Introduction

The climate change and global warming is a widespread problem in the world. Increase in the greenhouse gases is the reason of this climate change (Dettinger et al, 2004, 2). According to IPPC report, average annual temperature of the earth has been raised from 0.3° to 0.6° as a result of spreading the greenhouse gases and this value will increase from 1 to 3.5° by 2100. The main effects of the phenomenon are drought, extreme flood, snowmelting, storms and increasing air temperature in different regions. These phonemes are in the whole world but they are different from each other. Climate change is an important environmental challenge in recent years.

In the north Karun basin, higher than 2500 m in altitude, is covered mainly by snow. Therefore, the snowmelt water supply plays an important role in Karun River. We will analyze the effects of minimum air temperature on snow cover and discharge changes in Karun River. In this basin, snowfall supply of water is more than precipitation rate to whole basin.

According to previous studies in different regions in the world, annual rainfall has downward trend but heavy rains have upward trend. Average air temperature, maximum air temperature, minimum air temperature and evaporation have upper ward trend. In addition, flooding has an increasing trend. However, these parameters have caused decrease in water resources.

The global effects including temperature increase, melting of polarized ice, and global sea level rise are the main results of that the climate changes. Among the negative effects are Non-uniformly distributed rainfall, increase and continuity of the droughts and finally on water resources in all over the world.

Materials and Methods

North Karun watershed is 2300 km^2 in area in south west Iran. This is one of the important basins in supplying water resources in southwest Iran. The volume water as resources is almost 10billion m^3 in North Karun basin.

The hydrologic data were recorded by power ministry and meteorological organization in 1984-2014. These data are including air minimum temperature, ice daily, snow cover and river discharge.

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Results and Discussion

In this research for change assessment, simulation and forecasting the minimum temperature, we have used meteorological data from 4 synoptic stations in the North Karun Basin. We have divided research period in the stations into 2 parts: 30 and 25 years. Therefore, the purpose of this research is to evaluate changes of minimum temperature in the past and to forecast it in the future. We have used CMIP5 for future climate change projections over the HNZ under a very-low forcing scenarios (RCP2.6), a medium stabilization scenarios (RCP4.5) and a very high baseline emission scenarios (RCP8.5). CMIP5 data were interpolated to the spatial scale (0.4˚×0.4˚). We have also made a downscaling by MATLAB software (0.2˚ ×0.2˚). In the following, correction model is used in accordance with the equation:

$$T'_{GCM,Fut} = (\overline{T}_{Obs} - \overline{T}_{GCM,His}) + T_{GCM,Fut} \quad (1)$$

We have also used indexes Bias, RMSE and R for assessment models to apply them for forecasting data in North Karun basin. The models of CMIP5 under, RCP4.5 and RCP8.5 have been utilized in this study. The output CMIP5 and scenarios RCP4.5 and 8.5 is comparedwith CMIP5 and MNA-44_ICHEC-EC, RCP4.5 scenario choice for simulation and forecasting.

Eventually temperature changes were evaluated. In addition, we have used to change snow cover of MODIS TERRA and Aqua satellite Image monthly for 2000-2014. An aspect of technical analysis is to predict the future movement of a stock based on past data. Trend analysis is based on the idea that what happened in the past gives an idea of what will happen in the future. A trend can be considered as the general movement over time of a statistically detectable change. The MK test is usually used to assess the trend of a time-series. The purpose of Mann-Kendall (MK) test is to assess if there is a monotonic upward or downward trend of the variables of interest over time. A monotonic upward (downward) trend means that the variable consistently increases (decreases) through time, but the trend may or may not be linear. The MK can be employed instead of a parametric linear regression analysis to test if the slope of the estimated linear regression line is different from zero. The following equation can be used:

$$E_i = \frac{n_i(n_i - 1)}{4} \quad (2)$$

$$V_i = \frac{n_i(n_i - 1)(2n_i + 5)}{72} \quad (3)$$

$$U_i = \frac{(\sum t_i - E_i)}{\sqrt{VI}} \quad (4)$$

$$Ei' = [N - (n_i - 1)](N - n_i)/4 \quad (5)$$

$$Vi' = \frac{[N - (n_i - 1)](N - n_i)[2(N - (n_i - 1))] + 5}{72} \quad (6)$$

$$Ui' = \frac{-(\sum t_i' - E_i')}{\sqrt{V_i'}} \quad (7)$$

Conclusion

The climate change can cause water stress. The increase in air temperature, drought and decrease in water are the signs of climate change in the whole world. The results indicate that there are changes in minimum air temperature, snow cover and discharge in North Karun Basin. The results show that minimum air temperature has upper ward trend at 95% and it is increasing between 0.1Cº to 4.4Cº in particular at cold season (November, December, January, February). In addition, snow cover, ice daily and discharge have decreasing trend. The results of simulator by GCM represent that air temperature trend will perpetuate in this basin at future period. Therefore, the increase in air temperature minimum, decrease in snow cover and discharge can cause water stress in North Karun Basin and Karun River. The results show that increased minimum temperature of air cause decreasing water resources and hydro-electric supply in the feature.

Keywords: Northern Karun, air minimum temperature, trend, runoff, snow cover.

Regionalization of Susceptibility to Drought in Najaf Abad Basin

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Extended Abstract

Introduction

Drought as a complex phenomenon involves extensive research. Therefore, being aware of the drought situation in high risk areas can reduce the damage and problems and enhance the ability to manage natural and agricultural resources. Fortunately, the advent of new technologies for identifying and zoning in high risk areas made it possible to conduct extensive research in this field. Isfahan province is located in the Central Plains of Iranwith dry weather conditions. Decrease in rainfall, over exploitation of wells and misuse of water resources play an important role recently drought in the province. Najaf Abad Plain is one of the Basins located in this province. Placement of a modern irrigation network, a sharp drop in groundwater levels and reduction of water discharge are important factors in this area. Thus, this area is selected as study area in this research. Unfortunately, frequent droughts in parallel with drying up of Zayanderood River brought about undesirable effects on the local economy in the recent years. The aim of this study is to help the researchers and decision makers choose proper management decisions of water resources in this area by identifying the areas susceptible to drought.

Materials and methods

In this study, we have used meteorological data and satellite images in a 25-year period. According to rainfall data from weather stations, three years of high rainfall (1995), low rainfall (2008) and normal year (2015) were selected and the amount of actual evapotranspiration was calculated using SEBAL algorithms on the ETM+ images and Penman-Monteith method on meteorological data. For this purpose, 36 images of landsat5, and 8 ETM+ were downloaded from the earth explorer site in these years. The period covered by each image found and the amount of monthly reference evapotranspiration was calculated using Penman-Monteith and meteorological data. Monthly reference evapotranspiration were multiplied by the daily evapotranspiration values and monthly actual evapotranspiration. Annual evapotranspiration was obtained by monthly actual evapotranspiration values. Then, the rainfall zoning map was

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prepared by interpolation of rainfall data from weather stations. Fuzzy Method and weighted overlay are a method to determine the areas susceptible to drought. Fuzzy method was used in this study because Fuzzy method shows better and clearly results. Finally, the sensitive areas were identified by overlaying fuzzy maps of rainfall and evapotranspiration in these three years.

Results and Discussion

Comparing the results of Penman-Monteith and SEBAL algorithm showed that the root mean square error of these two methods is about 0.21 and 0.73, respectively. In other words, 73 percent of evapotranspiration in Penman-Monteith method can justify the changes resulted from the SEBAL method and so can be trusted by regression equation. Because the determination coefficients of the regression are high, so it can show changes in dependent and independent variables. Results indicate that the evapotranspiration value highest in 2008 and lowest in 1995. The result shows that South and Southeast regions of Najaf Abad are more sensitive than other parts and they have higher risk of drought in 1995. Because in this part evapotranspiration is high and rainfall is low. Therefore, the drought sensitive areas have been identified. In 2008, the probability of drought in those regions has continued. The difference is that the number of pixels in 1995 showed less sensitive to drought than those in 2008. While at the same area in 2008 more pixels have been involved in drought with large scale mapping of sensitive areas. In addition to the central and western regions of Eastern areas, there are also many other susceptible areas to drought. This result matches with the result of Standardized Precipitation Index (SPI). Because the Standardized Precipitation Index (SPI) shows that intense meteorological drought has occurred in this area. However, the zoning map shows sensitive area. The southern and southeastern areas are out of drought situation and they have favorable conditions in 2015. This result shows that rainfall is better in this part of the basin.

Conclusion

The results of this research help experts identify the areas prone to drought events. We need proper planning to reduce the effects of drought in the areas with high risk more than before based on the map resulted in this research. It is recommended that the methods used for irrigation and cropping patterns are according to region and the effects of drought.

Keywords: drought, evapotranspiration, rainfall, remote sensing, GIS, Najaf Abad Plain.

Modeling the Relationship between Land Surface Temperature, Topography and Vegetation Cover Using Landsat 8 Satellite Imagery

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Extended Abstract

Introduction

Land surface temperature plays a vital role in a wide range of scientific researches including climatology, meteorology, hydrology, ecology, geology, medical sciences, design and optimization of transportation services, fire location and especially in calculating the real evaporation and transpiration. There are some determining factors affecting the land surface temperature, such as, the kind of surface elements, topography conditions, environmental conditions, climate condition and the amount of emitted energy from the sun. Recognition and analysis of the relation between the land surface temperature and various factors are so critical. The remote sensing method has a widespread application in preparing the land surface temperature images due to the extensive covering and continuous data. The purpose of this study was to investigate the effects of vegetation cover indices and topographic factors on land surface temperature and modeling the relationship between land surface temperature, topographic conditions and vegetation cover using Landsat 8 satellite imagery.

Materials and Methods

In this study, sensor reflective bands OLI, Jimenez and Sobrino method were utilized to calculate the emissivity of the available phenomena in the area. By using TIRS Landsat 8 sensor thermal bands 10 and 11 and utilizing Split-window algorithm, the land surface temperature was calculated. Topography parameters, such as elevation, slope, aspect and vegetation were extracted using digital elevation model and NDVI index, respectively. Then, the relation between the land surface temperature and topography factors in diverse conditions was investigated by statistical analysis, and then, the validity of relations was analyzed with a confidence level of 95%. For this purpose, we employed ENVI 5.3, ArcGIS 10.4, ERDAS IMAGING 2014 software as well as SPSS statistical software.

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Results and Discussion

The obtained results indicates that the study area has a uniform vegetation cover in most areas and a high percentage of the areas have the NDVI of 0.45-0.6. Nonetheless, due to the diversity in topographic and climatic conditions the area surface temperature is inhomogeneous and non-uniform. Consequently, there is no relation with a high correlation coefficient between the land surface temperature and vegetation in the area. However, there is a reverse linear relationship between the land surface temperature and vegetation in the area. This relation gains a higher correlation coefficient in the form of linear relation compared with second order polynomial, Pearson, and logarithmic equations. The areas with southern and southeast slope have higher land surface average temperature compared to other aspects during imaging due to their position exposed to direct sun radiation. The temperature average is different in various slopes. Investigating the relations of temperature and elevation independent of slope parameters and slope aspect, gives rise to an increase in the correlation coefficient between the two parameters. The relation of the land surface temperature and elevation, regardless of slope and aspect for the studied area, is a reverse linear relation with the correlation coefficient of 0.54, whereas for the relation between the land surface temperature and elevation in the western slope and slope of 40-50 degree, there is a reverse linear relation with the correlation coefficient of 0.76. Moreover, in investigating the relation between the land surface temperatures with topographic conditions, simultaneous consideration of both elevation and slope variables as independent variables for modeling the dependent variable of surface temperature reveals a strong relation. The addition of vegetation index parameter to relation independent parameters brings about a rise in relation's correlation coefficient. For instance, relation's correlation coefficient of the land surface temperature with elevation independent variables, slope, and vegetation in the western, northwest and southeast direction, are 0.84, 0.81 and 0.8, respectively. All the obtained relations are investigated in the confidence level of 95%, and validity of relations was confirmed by "t" statistic and search for relations' coefficients.

Conclusion

Results of this research have indicated that taking elevation, slope, aspect and NDVI parameters independently for modeling the land surface temperature, can give adverse results and by simultaneous application of both topographic parameters and vegetation and also their combination, as dependent parameters, the land surface temperature can be precisely calculated. In addition, for accurate modeling of the land surface temperature all topographic, climatic and environmental conditions for the area should be taken into account. The thermal and reflective remote sensing technology are economical, fast and effective due to several positive aspects to provide uniform topographic, vegetation data and environmental parameters. So, further researches and investigation are necessary.

Keywords: vegetation cover, land surface temperature, topographic conditions, modeling.

Effects of Coastal River Dynamics on Shoreline Sedimentological Characteristics and Movement (Case Study: Western Makoran Coastal Plain, Iran)

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Extended Abstract

Introduction

More than half the world's population lives in coastal regions (Bird, 2008). The shorelines are unstable zone that comprises marine and terrestrial domains very sensitive to a variety of geological process; Waves and tides play a most important role in the coastal dynamics, and their mutual interaction accounts for redistribution of the sediment budget causing accumulation or erosion (Dabrio, 2000). The coastal ocean, where land, air and sea meet, is a region of very high physical energy and biological diversity that is heavily exploited by man (Murthy et al., 2002). Tidal flats are low-lying areas where alternately covered by water and exposed to the air each day (Gore, 2010). Analysis of forms and coastal conditions provides a valuable key for coastal management. Many studies have been conducted on the impact of waves on beach (Bagnold, 1939; Ross, 1955; Hayashi and Hattori, 1958). In a related research on western Mokran coastal plain, Shayan et Al. (2014) found that in terms of forming processes and according to the coastline curves and rivers' hydrodynamics, coastal sand masses were located by coastal waves. The aim of this study is to identify the effects of fluvial flows on sedimentological characteristics of shoreline in the western part of Mokran coastal plain, Iran.

The study area is located at 25^{o} 31'- 27^{o} 09'N, 56^{o} 54'-59^{o} 19'E, in western part of coastal plain of Mokran, south Iran in the north coast of Oman Sea and west to Strait of Hormoz. In general, the study area could be assumed a dry land with very low rain of windy, sand storm, torrent shower, thunder-storm, higher humidity and hazy down (Akbarian et al., 2006). From geological aspect, this area is affected by general construction of the Mokran (Makoran) region and mainly composed of shale, marl and sandstone layers.

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Materials and Method

The data of this research are including spatial distributions of tidal zones, velocities and directions of wind, fetch length, the morphologic and sedimentological characteristics including granulometeric and morphoscopic indicators. Geologic and topographic maps, satellite images, GPS, binocular microscope and computer software including ArcGIS and Gradistat also were used as the research tools. For sediment measurement studies, 8 samples were taken from shoreline. The samples were analyzed using ASTM standard sieves and Gradistat software from granulometery aspect. Morphoscopic indicators were investigated by 40X binocular microscope. After that, by using wind data, WRPlot View software and Molitor equations, wave characteristics were studied and the wave roses were plotted also.

Results and Discussion

It can be concluded that the processes of marine sediment transportation are in force across the range of this coastal zone. Waves and tides deliver sediment to the intertidal zone, so that wind is able to transport it landwards from the intertidal to the supratidal area (French, 2001).

Particle size windows (PSWs) are interpreted as reflecting different modes of sediment transport and deposition (Clarke et al., 2014). A beach can be composed of a wide variety of materials of many sizes and shapes (Dean and dalrymple, 2004). Based on sedimentological characteristics, tidal deposits are comprised of fine-grain to very fine sandy materials. In general, these grains are angular to sub-round and their surface textures are bright. The samples don't have clay hunks but have small fragments of marine shells.

Waves are crucial in stirring up sand in the nearshore; variations in direction of wave approach, combined with irregularities in sea floor topography results in refraction or bending of wave crests and this initiates variations in energy levels received along a shoreline (kidd, 2001). On south coast, west and southwest waves are predominant from October till the end of June; In July, the percentage of southeast waves is considerably increased except of West Jask Cape. This situation continues till the end of September. Thus, the sediments brought by rivers, are drifted in different directions by waves along with coastline sharp curvatures.

Conclusion

The results of this present study show that coastal area sands were transported by the sea processes as a final stage. But morphometric indicators represent high impact of fluvial processes on coastal deposits. It can be concluded that sources of the analyzed sediments is adjacent to mouth of the rivers in the region; the transportation ability of sea processes is less than performance need to eliminate fluvial effects on coastal deposits and sediments.

Keywords: coastal geomorphology, sedimentological processes, shoreline, West Mokran plain.

Spatio-Temporal Analysis of the Accuracy of TRMM Satellite Data to Estimate the Severity of a Drought Based on Precipitation in Central Iran

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Extended Abstract

Introduction

Precipitation data have been widely used in many earth science applications ranging from crop yield estimates, tropical infectious diseases, drought and flood monitoring. However, in many tropical regions and parts of the mid-latitudes, rainfall estimates still remain a major challenge due to sparse rain gauges. To better develop applications for these regions, it is necessary to have rainfall data with adequate spatial and temporal resolutions. Precipitation data plays the key role in drought monitoring. Rain gauges are the main measuring methods for precipitation but they are concentrated in developed countries and are spare in developing countries and remote areas in the world. Researchers have shown that remote sensing techniques using space-borne sensors can provide an excellent complement to continuous monitoring of rain events both spatially and temporally. Microwave and Visible/Infrared are the main forms of remote sensing technologies; both have varied advantages in terms of imaging accuracy and spatial-temporal resolutions. Thus, the fine spatial-temporal precipitation products need the coalescence of both. Tropical Precipitation Measuring Mission (TRMM) carrying sensors on precipitation provides the opportunity for fine spatial-temporal precipitation products. In this research for Central Iran, the precipitation data of TRMM satellite was evaluated and used to estimate the severity of a drought based on precipitation.

Materials and Methods

Central Iran is located between 27N-37N latitudes and 48E-61E longitudes and has an area of about 837,184 km^2. There are 50 synoptic stations within the area. The data are including monthly precipitation depth from both synoptic stations and TRMM data (3B43 V.7, in ASCII

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format). A five year (2001–2005) period were chosen for the analysis. The accuracy of precipitation data that are used from synoptic stations and TRMM satellite are provided by the source provider. Firstly, the evaluation of TRMM satellite data was measured using coefficient of determination (R^2), mean error (ME), mean absolute error (MAE) and root mean square error (RMSE) in 95% confidence levels. Then, TRMM remote sensing data are used to provide the required data for precipitation drought index in central Iran to make a mapping of the spatial distribution of drought. Finally, accuracy of the PDI drought index based on satellite data carried out using the evaluation criteria was compared with drought spatial distribution map of the PDI based on ground-based precipitation measurements data and soil moisture values of 50 synoptic stations.

Results and Discussion

In this study, monthly rainfall values estimated by satellite products were copared with those of rain gauge observations in Central Iran. The validation of TRMM 3B43 data were performed at monthly, season and annual scales. The average of monthly, seasonal and annual rainfall for all selected synoptic stations and TRMM data were compared during the period 2001-2005. TRMM data at all time steps, except August, estimates the average of monthly rainfall more than observed data. The correlation coefficient between the average of monthly rainfall, seasonal and annual rain gauge and TRMM has shown that this ratio is variable from 0.45 to 0.94 for all time steps and the average of this ratio is equal to 0.76. The highest and lowest values of R^2 at monthly time step obtained 0.92 for April and 0.45 for June. In this time step, the lowest and highest values of statistical error criteria are obtained for June and January, respectively. In seasonal time step, the highest and lowest correlation is related to the spring and summer with determination coefficient (R^2) of 0.94 and 0.64, respectively. In this time step, the lowest and highest values of statistical error criteria obtained for summer and winter, respectively. Generally, TRMM data performs best in summer, but worst in winter, which is likely to be associated with the effects of snow/ice-covered surfaces and shortcomings of precipitation retrieval algorithms. The correlation coefficient for the annual time step is equal to 0.83. The results of statistical criteria showed that TRMM rainfall data in all time steps overestimated for all months except for August. The lowest to the highest values of statistical error criteria were obtained for monthly, seasonal and annually rainfall data, respectively. In the next step, spatial distribution of drought based on measured data from ground stations and TRMM data in the period 2001-2005 is obtained from Precipitation Drought Index (PDI) method in study area. The results of the statistical criteria of conformity assessment in PDI spatial distribution map based on TRMM data with corresponding pixels of spatial distribution map based on the synoptic stations precipitation data showed that the drought severity map had a high precision and good conformity with ground data (R^2=0.89, ME=0.08, MAE=0.14, RMSE=0.19). Also, the results of the evaluation criteria showed that PDI index in accordance with soil moisture values had the significant correlation (0.71) and the lowest estimation error (2.33).

Conclusion

In this research, for estimation of drought severity index based on precipitation, the monthly precipitation data of TRMM satellite (3B43) was evaluated. The evaluation was measured using coefficient of determination (R^2), mean error (ME), mean absolute error (MAE) and Root Mean

Square Error (RMSE). This analysis has demonstrated that the TRMM rainfall products show very good agreement with gauge data over the selected area of Central Iran on monthly timescales and 0.25° space scales. said it can be concluded that the satellite-based rainfall, e.g. TRMM data, have good potential for useful application to hydrological simulation and water balance calculations at monthly or seasonal time steps. This can be useful for the regions where rain gauge observations are sparse or of bad quality. However, the TRMM can overestimate the rainfall in some years and areas and underestimate in other years and areas, and failed to detect the extreme rainfall. This can reduce the accuracy of stream flow simulation at short time steps and other applications including drought monitoring and flood forecasting. The conclusions indicate that it is necessary to further develop algorithms of satellite-based rainfall estimation in terms of both the accuracy and spatiotemporal resolutions of rainfall estimates.

Keywords: evaluation, remote sensing, satellite rainfall, drought, Central Iran.

Spatial-Temporal Modeling of Thunderstorm Occurrence in the Northwest Iran

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Extended Abstract

Introduction

Thunderstorms are formed by overheating the earth's surface in air masses or in the weather fronts especially cold front (Kaviani and Alijani, 1991). These storms are part of climatic destructive phenomenon that cause irreparable damage as hail, heavy rainfall and thunders to facilities of farms and houses every year. Thus, it is necessary to study this phenomenon. The climatic phenomena such as thunderstorms, as random phenomena, are not exactly predictable and can gain useful information by monitoring them, that this is possible through the laws of probability. Markov chain is a common method for modeling random phenomena (Wilks, 2006). This model is one of the statistical methods to examine the temporal relationship between the various climatic phenomena and it is the most common method to determine the frequency of climatic phenomena sequences. In this method, the probability of occurrence of a climate state is projected at time t based on its condition at the time before (t-1) (Alizadeh, 2001). This model is widely used in various fields including atmospheric sciences. In recent decades, climate researchers have used this model in various fields such as rainfall, drought, thunderstorm, wind speed and solar radiation. Thunderstorms are known as one of the most important atmospheric phenomena, due to the obvious climatic function and imposition of natural and human catastrophic effects. Many scholars and researchers pay attention to it in the various branches of science. The aim of this study is to evaluate the occurrence probability and return period of thunderstorm using Markov chain model and its spatial analysis in the Northwest Iran.

Materials and Methods

For analysis of spatial-temporal modeling of thunderstorm occurrence in the Northwest Iran we have used meteorological data for 19 synoptic stations during the period 2000-2015. Markov chain models are including stochastic processes that are widely used in discrete time series modeling. Time dependence of random variables is expressed through autocorrelation coefficient or transition probability matrix (Ashgartousi et al., 2003). Transition probability matrix is a square matrix, depending on its number of states that includes the number of possible *n* combinations of the transition probability from one state to another. The first order Markov

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chain is the main form of the Markov chain which consists of a discrete time series which the behavior of the series in the next time step depends on present not on past time steps. If possible states for the time series of thunderstorm days are considered in normal days (0) and thunderstorm days (1), the state in the next step could be between of 0 and 1. We have calculated the matrix elements and transition probabilities of some important characteristics of the data:

a) The frequency of occurrence of two states and the change of the states were calculated and transition frequency matrix was determined. b) The transition probability matrix was calculated using the maximum likelihood estimation method. c) After determining the transition probability, it is necessary to examine the fit of Markov chain model on data series. To this purpose, the chi-square test (χ^2) is used. d) The persistent probability for each state was calculated using transition probability values. e) The possibility of occurrence of the period of 1-5 days was predicted. f) The frequency of occurrence of the period of 1-10 dusty days was estimated. g) The n-day return period was calculated.

Results and Discussion

To examine the sequence of thunderstorm days in the Northwest Iran, at first the frequency of normal and Thunderstorm days were calculated. The results show that in April, the highest frequency of days with thunderstorms is in center, in May in northwestern areas and in June and July in central areas, can be seen in the northwest. The lowest frequency can also be seen in the southern parts of the study area. Frequency and transition probability matrix was calculated for time series of thunderstorm days. Then, the fitness of the two- state first order Markov chain model were studied using χ^2 test and the results showed that the states frequency follow a two-state Markov chain. In order to predict the thunderstorm period, at first, the frequency of *n* days' period of thunderstorm days was projected in April, May, June and July for stations. The results show that by increasing the duration of period, the frequency of the dusty days is reduced.

The estimate of *n* day continuity of thunderstorm days represents the abilities of the Markov chain model. In April, the occurrence of two-days in the center and west part of study area is more possible. In May, there is the highest frequency of thunderstorm days, the probability of two- days increased to 24%. In June, the average probability of two-days is 23%. The probability of three-days in April reduced an average of 6%. In May and June, the probability is about 10%. In these months, the probability of three-days has reached 15% in North and Northeast. In July, the probability of three-days has reduced; while, in the western part it is estimated up to 14%. Return period of one-day in all stations is on average 1.5. This means that every 1.5 days, a one-day will be in the Northwest Iran. For increase in duration of thunderstorm, the return period increases, it means that it takes a long time of five-thunderstorm days again. Spatial distribution of occurrence probability of thunderstorm days in the long-term (persistent probability) showed that in April, the lowest probability of thunderstorm is in the Northeast and the highest probability is in the center. In May and June, the lowest probability is in the southern parts and the highest probability in the North and Northwest. In July, the lowest probability is in the South and Northeast and the highest in the West and Northwest. In general, the probability of days with thunderstorm in the south and northeast is less than other areas.

Conclusion

The results of this research show that in all stations, frequency of normal days is more than the days with thunderstorm. The highest frequency of days with thunderstorms in April is in center, in May in northwest and central areas and in June and July in the northwest. The estimate of 1-10 days continuity showed that by an increase in the duration of period, frequency of dusty days. The probability of the occurrence of two and three-days is low in the South and Northeast and high in center and Northwest. Return period of one-day on all stations and in all months is 1.5, but by increasing duration of dust, its return period increases exponentially. The spatial distribution of persistent probability matrix shows that the occurrence of thunderstorm in center, North and Northwest is more. In general, understanding of this phenomenon and its probability is important for implementation of prevention programs and management plans to deal with this hazard in critical areas.

Keywords: day with thunderstorm, Markov chain, occurrence probability, return period, Northwest Iran.

Morphological Analysis of Zarrineh-Roud River Using Rosgen Model

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Extended Abstract

Introduction

A basic belief in geomorphology says that 'form implies process.' Thus, numerous geomorphic classifications have been developed for landscapes, hillslopes, and rivers. The form–process paradigm is a potentially powerful tool for conducting quantitative geomorphic investigations (Shroder, 2013: 730). Streams typically have similar suites of channel morphologies, with repeatable patterns of occurrence, which resulted in numerous classification efforts (Roper et al., 2008: 417-427). Recent approaches for river classification focus on watershed analysis related to land management and stream restoration, using a hierarchical approach that nests successive scales of physical and biological conditions and allows a more holistic understanding of basin processes (Shroder, 2013: 739). One of the most widely used hierarchical channel classification systems was developed by Rosgen (1985, 1994, 1996, Shroder, 2013: 742). In the current study, Zarrineh Roud river channel planform are studied by using Rosgen geomorphological model in combination with HEC-RAS model.

Materials and Methods

This study is based on fieldworks and topographic maps of scale 1: 2000 (West Azerbaijan Regional Water Authority). The data from Sari-Qamish and Nezam-Abad hydrometric stations in the main stream and Qureh-Chay and Janaqa stations on the tributaries were used for calculation of return periods and discharge–stage relation. To determine the friction coefficient distribution of channel and floodplain, land cover maps was generated using Google Earth satellite imagery. Laboratory equipment including Van Veen Grab- Bottom Sampler, shakers, digital scales, and caliper were used for Sediment particle size analysis (granulometry). Rosgen (1985, 1994, 1996) hierarchical system was used to analyze river channel morphology. The Rosgen system uses six morphological measurements for classifying a stream reach-entrenchment, width/depth ratio, sinuosity, number of channels, slope, and bed material particle size. These criteria are used to define eight major stream classes with about 100 individual

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stream types (The Federal Interagency Stream Restoration Working Group, 2001, chapter 7: 29). In this research, some of these parameters were calculated using HEC-RAS hydrodynamic model. For steady, gradually varied flow, the primary procedure for computing water surface profiles between cross-sections is called the direct step method. The basic computational procedure is based on the iterative solution of the energy equation. Given the flow and water surface elevation at one cross-section, the goal of the standard step method is to compute the water surface elevation at the adjacent cross-section. The flow data for HEC-RAS consists of flow regime, discharge information, initial conditions and boundary conditions (HEC, 2010).

Results and Discussion

Zarrineh Roud River based on different variables, such as channel planform, geological controls, bed material and anthropogenic effects, was divided into five different reaches: Reach (1) from start point to Shahindejh industrial town; reach (2) from industrial town to Norouzlu Dam; reach (3) from this dam to Miandoab city; reach (4) from Miandoab to Chelik village; reach (5) from Chelik village to Urmia Lake. Reach (1) is type C3, which according to the slope and bed material divided into two sub-reaches: sub-reach C3b and sub-reach C3. Type C3 streams have a good recovery potential, moderate sediment supply, moderate streambank erosion potential and very high vegetation controlling. In this reach, the lateral dynamics of channel is low due to the geological control and low erodibility of bank material. Also, the bed incision is largely limited due to the presence of coarse material and bed armoring. Therefore, this reach is relatively stable. From starting point of reach (2) significant changes can be observed in the geomorphological characteristics of the Zarrineh Roud River. Floodplain width significantly developed and geological controls reduced. In this reach, Zarrineh Roud River becomes specific example of gravel Bed Rivers that extends to the downstream Norouzlu Dam. At the upstream of reach (2), the river is transformed into a type D4 stream. According to the field studies, high erodibility of bank materials along with poor control of vegetation are the main reasons to create the type D in some parts of this reach. Other parts of reach (2) are very specific example of type C stream that according to the slope and bed material, belong to the type C4. This reach shows complete characteristics of type C4 streams, so that, it has a high sediment supply, very high streambank erosion potential and very high vegetation control. In fact, vegetation cover combined with the erodibility of the streambanks determines the degree of lateral adjustment and stability of this reach. In this reach, most meanders are active. Lateral migration of meanders is accompanied by the mass failure in elevated clay banks. Reach (3), from downstream of Norouzlu dam to Miandoab city, in most sections, are converted into type G and type F streams. In fact, in this reach, a conversion has taken place from type C (C4 in upstream and C5 in downstream) to type G and type F due to very extensive anthropogenic interference. In this reach, sand and gravel mining is widely uncontrolled. River bed entrenched up to several meters (confined) and often isolated by steep and vertical banks from floodplain. Type G5, type F4 and type F5 streams have very poor recovery potential, very high sediment supply, very high streambank erosion potential and high vegetation control. This reach in terms of natural lateral dynamics is inactive. Based on the delineative criteria of Rosgen model, reach (4) have characteristics of the type C5b streams. In this reach, flood prone areas are reduced due to the human interference. Flood prone areas are mainly in accordance with scroll bars which developed in the convex sides of meanders. This reach due to the anthropogenic disturbances

does not have typical characteristics of type C streams and is better considered as a reach converted from type C to type F. Reach (5) is converted to a type E that according to substrate material and slope, divided into two sub-reaches: sub-reach type E5b upstream and sub-reach type E6b downstream. In this reach, floodplain is very broad and developed. Creation of a developed meandering pattern is related to the low stream power and cohesive bank material. This reach is also relatively stable.

Conclusion

Efficiency of Rosgen model upstream the reaches of Norouzlu Dam and final reach is relatively good and almost all sections are compatible with a type of Rosgen streams. In these reaches, river form and pattern largely indicate the processes governing river channel and river morphology controlled by variations of stream power and variability of bank and riparian conditions. In the both reaches (3) and (4), due to high control of anthropogenic factors, explanation ability of the Rosgen model is limited and incompatibilities are observed in determining the type of Rosgen streams. These two reaches are critical reaches along the Zarrineh Roud River. Rosgen (1997) proposed four priority in its geomorphological approach to restoration of incised rivers that prioritized as follows: Conversion of G and/or F stream types to C or E in previous elevation w/floodplain; Conversion of F and/or G stream types to C or E; reestablishment of floodplain at existing level or higher but not at original level; Conversion into a new stream type without an active floodplain but containing flood prone area. Conversion of G to B stream type or F to Bc; Stabilization of channel in place. Given that rehabilitation and restoration of type G and type F are difficult, it is better to apply restrictions in relation to sand mining regardless of the conversion the reach (4) (downstream Miandoab) to type G or type F. For type F and type G reaches is recommended, because of the high population density in the region and increase in the probability of flood event, the second priority, conversion of F and/or G stream types to C or E and reestablishment of floodplain at existing level or higher but not at original level.

Keywords: morphology, planform, Rosgen model, HEC-RAS model, Zarrineh Roud River.

Phenological Stages and Chilling and Heating Accumulation of Apple Tree under the Climatic Conditions of Karaj

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Extended Abstract

Introduction

Identification of the phenological stages and the heating and chilling accumulation of fruit trees on the basis of the climatic conditions is of great importance to discover the potentialities and to identify the compatible species. Most deciduous trees need chilling and heating accumulation to have complete growth. In fact, chilling accumulation is necessary to overcome the dormancy or sleep period and heating accumulation is necessary for flowering and the change of phenological stages. The study of the phenological behavior of fruit trees is important as the impact of environmental conditions. Weather and climate constitute a key determinant in successful production of deciduous fruits. Identifying the phenological stages and climatic condition requirements for fruit trees can help promoters and gardeners to choose the best and most suitable varieties.

Materials and Methods

This study as statistical-field is an applied research. In the field study, in order to identify the time of the occurrence of phenological stages and the temperature thresholds, a series of daily and weekly visits and writing field were regularly conducted in the growing season of the crab apple tree. For this purpose, a commercial fertile garden with an appropriate cultivated land area of crab apple tree was selected. The garden complex is located adjacent to Karaj Meteorological Station, Alborz Province, Iran. In the process of conducting field observations, with the assistance of gardening and horticulture experts, , four crab apple trees were selected from a set of one hectare of apple trees in different parts of the garden as an Iranian early-season variety. The phenological stages and temperature conditions were recorded on the basis of principal and secondary codes of the BBCH scale with daily and weekly visits. In the process of field visit, the phenological conditions of the trees were examined and compared, and ultimately, the final date and temperature threshold of the stage were recorded.

The required statistical data for the hourly and daily climatic parameters from 1985 to 2014 were obtained from the Iranian Meteorological Organization as well as Alborz Province Meteorological Department. The chilling requirement was determined through the models as the

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Chilling Hours (CH), UTAH and dynamic (CP or Chill Portions) models, and the heating requirement was identified through the effective and active growing degree day and growing degree hour models on the basis of Anderson and Richardson's models. The Mann-Kendall's nonparametric method was also used to determine the process of temperature changes.

Results and Discussion

In the early-season apples, the end and beginning of the sleep or dormancy period occur in late February and mid-October. The longest phenological stage is the fruit development stage, starting from the end of flowering in the first ten days of April till the end of June and early July. In the Karaj climate, early-season apples begin to sprout in late February and are completely asleep in late October. Its winter chilling accumulation was obtained as 1027 chill hours based on the CH model, 1771 chilling units based on the UTAH Model, and 76 chilling portions based on the dynamic (CP) model. Based on Anderson's model, 7203 growing degree hours (GDH) and based on Richardson's model, 12086 growing degree hours (GDH) are required for heating accumulation from the end of dormancy to full flowering. During the whole growth period for the seven main phenological stages, 2223 and 3026 effective and active growing degree days are required. The increase in the hourly temperature, especially the minimum temperatures, is obvious during dormancy at the end of the cold season at most hours of the day. The temperature has a significant upward trend in February and March. The climatic conditions of Karaj have the necessary chilling and heating accumulation for cultivation of the early-season varieties of crab apple. Given the rising hourly temperature, the early emergence of flowering in the middle of the winter in the future and the risk of frost are not unexpected.

Conclusion

The output of chilling accumulation models on the basis of long-term hourly temperature data from Karaj Station showed that there is sufficient chilling accumulation for the early-season varieties of the crab apple tree in Karaj climate. The highest chilling accumulation occurs during the dormancy period in December, January and February. The chilling accumulation results can be used as a model for other deciduous trees. The climatic potential of the region provides chilling accumulation for early-season varieties, but it is limited for late-season varieties with high requirements. In terms of heating accumulation, there is no specific limitation for the apple trees.

The results of hourly temperature variations in the cold season of the year, i.e. the dormancy period of the fruit trees in the study area indicated that the air temperature has an increasing trend at the end of the winter season, especially in February and March. This increasing trend is more visible during the night and morning hours when the minimum temperatures occur. This significant increase in the hourly temperature of the cold season of the year and the dormancy period of the fruit trees, in the one hand, will reduce the chilling accumulation of the apple trees and other similar trees, and on the other hand, by accelerating the early emergence of germination and flowering phenological stages at the end of the cold season will bring about a serious risk of late-frost and cold for the early-season apple trees as well as other fruit trees. Hence, it is important to make necessary decisions for dealing with the frost and cold climate crisis.

The results of this study indicated that the temperature conditions contain the most important climatic necessity for the fruit trees and that fruit trees are highly responsive to any temperature

changes. The use of hourly and daily temperature data is of great importance in measuring the chilling and heating potentials in order to select the compatible species with the climatic conditions of each region for preventing the loss of capital and resources.

Keywords: apple tree, chilling requirement, growing degree hours, heating requirement, phenology.

Comparison of Temporal and Spatial Changes of Groundwater Level in Isfahan-Borkhar, Najafabad and Chadegan Plains

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Extended Abstract

Introduction

Isfahan province is one of the driest provinces in central part of the country where two-thirds of its water requirement is supplied by groundwater resources. In recent years, with population growth and the increase of water demand in different sectors of agriculture, industry, drinking, and health, groundwater resources have faced a lot of pressure. Thus, understanding the behavior of the groundwater body and its long term trends are essential for making any management decision in the areas. Mann–Kendall statistical test has been commonly used in many researches to assess the significance of trends in hydro-meteorological time series. Geostatistical analysis has been theoretically defined and applied by many researchers and they have emphasized that geostatistics is a management and decision support system tool for analyzing spatial and temporal variations of groundwater level fluctuations. Geostatistical approaches can provide more helpful, reliable and efficient tools to increase the number of measurement points at un-sampled locations, and variogram analyses for examining structural relationship of data (Rakhmatullaev et al. 2011).

Materials and Methods

In this study, the temporal and spatial variations of groundwater level for Isfahan-Borkhar, Najafabad and Chadegan plains, is investigated with a 25 years period (1990-2015). Monthly water level data have been collected from 29, 40 and 8 observation wells in Isfahan-Borkhar, during the study period. Precipitation data from synoptic, climatology and rain gauge stations were used in this research.

The trend analyses have been conducted at monthly, seasonal and annual scales using Mann-Kendall Test and Sen's slope estimator nonparametric methods by MATLAB.AB 7.11 software. The Mann-Kendall test is a non-parametric method used for trend analysis of time series data. In

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this method, the presence of a statistically significant trend evaluated using Z value (equation 1).

$$z=\begin{cases}\dfrac{S-1}{\sqrt{Var(S)}} & S>0\\ 0 & S=0\\ \dfrac{S+1}{\sqrt{Var(S)}} & S<0\end{cases} \quad (1)$$

A positive value of Z indicates an increasing trend and a negative value indicates decreasing trend.

In this research, the null hypothesis (H0) stated that "there is no trend in time series of groundwater levels". The hypothesis is rejected if the absolute value of Z is greater than ±1.96 and ±2.58 in 5% and 1% level of significance, respectively. If the value of Z is out of this range, the null hypothesis is accepted and there isn't any trend in time series (Yin et al. 2015).

For investigation of the relationship between groundwater level depletion and rainfall for each of plain, the linear regression was done in annual scale. The groundwater level hydrograph was drawn also for each of plain during 25 years (January 1990 to October 2015). Prior to the geostatistical estimation, it requires a model to compute a semivariogram for any possible sampling interval. The experimental semivariograms were fitted with various theoretical models like spherical, exponential, Gaussian, linear and power in GS^+ software. The underground water level zoning maps were prepared by Ordinary Kriging method for every year of the study period. Spatial zoning maps were prepared and ultimately, an iso-falling map was created at the beginning and end of the study in ArcGIS 10.

Results and Discussion

The spatial distribution of trend by the Mann-Kendal test for annual groundwater level data indicated a general trend in all plains where most piezometers groundwater level is negative. The piezometer wells with positive trend were very low and the most positive trend is related to Isfahan plain. In Chadegan plain there wasn't any positive trend in piezometers level.

The investigation of trend line slopes revealed that in average, the groundwater level of Isfahan-Borkhar, has been decreased about 0.468, 1.12, 0.638 m y^{-1}. The general trend of the groundwater level hydrograph shows that the level and storage of water is continuously decreased in the last years.

Gaussian variogram model was the best for spatial structure of these data. Generally, the spatial pattern of zoning groundwater maps indicated that direction of groundwater flow is northwest to southeast on all study plains. As well as, the iso-falling map showed that groundwater level has dropped in most parts of the plains during the study period. This was in agreement with the results of the research by Rahmati et al. 2014, Azareh et al, 2014, and De Brito Neto et al. 2016. The cause of this agreement could be a vulnerability of arid region ecosystems into human interference and other stress factors.

Conclusion

Due to the lack of rainfall trend in most of the stations in the study area and low correlation between rainfall and groundwater level change, the major cause of reduced groundwater could be related to human factors. Overexploitation, as a result of population growth, and increasing

number of wells are the most important factors in decreasing of the groundwater table. Therefore, the decision is required to manage groundwater in the study area. It is necessary to immediately practice water conservation methods and water harvesting systems in the study area to prevent the causes of more damages to the available water resource.

Keywords: groundwater level, aquifer hydrograph, zoning, Mann-Kendall, Sen's slope Estimator.

Accuracy Evaluation of the Outputs of Regional Climate Models in Iran

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Extended Abstract

Introduction

All studies in the field of assessment of climate change impacts needs climate data with different spatial and temporal scales. The lack of temperature and precipitation data with high spatial resolution is a major limitation to analysis of future climate change. In addition, the output of the models has the error that needs to be corrected; otherwise, they will make a significant bias for assessing the effects of climate change. Therefore, identifying the best regional climate model for downscale the global climate models is essential to better understanding of climate conditions in the local and regional scale. In the last few years, use of various regional climate models for producing a multi-member set of the downscaled data in the CMIP5 project by World Climate Research Program (WCRP) in action with Coordinated Regional climate Downscaling Experiment (CORDEX) was established as an input to the researches about the impacts of climate change and adaptation ways. The main objective of this research is accuracy evaluation of different model outputs of the CORDEX project with different domain and resolution in Iran.

Materials and Methods

In the CORDEX project, there are two domains that covering Iran. These two domains are North Africa-Middle East (CORDEX-MNA) and South Asia (CORDEX-WAS). To do this research, daily output of precipitation, maximum and minimum temperatures in the period of 1990-2005 for three regional climate models with a special resolution of 0.22° and 0.44° are performed by three international meteorology institutes, available at ESGF web site (Table 1). Daily observation data recorded in 304 synoptic stations in Iran for the three variables were collected from Iran Meteorology Organization and transferred to a matrix with 3044×5844 dimensions. Then, several scripts were written in the MATLAB software to extract the model data in Iran and compare model output and observational data with two conditions. The first

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condition is in the output model resolution of 0.44° (spatiotemporal matrix with dimensions of 5844×740), the observation station should have a distance of less than 25 km, and the next condition is in the resolution of 0.22 ° (spatiotemporal matrix with dimensions of 5844×3218) should have a distance of less than 12 km. The difference between observation values and its corresponding estimated values were investigated with statistical method such as Mean Error (ME), Pearson Correlation Coefficient, Root Mean Square Error (RMSE) and Standard Deviation (SD). We also used Box-Whisker plots and Taylor Diagram to find the best regional climate model.

Results and Discussion

The precipitation accuracy of regional climate models output presented by different meteorological institutes (Table 1) was evaluated by observational data in two domains, CORDEX-MENA and CORDEX-WAS, in Iran (Fig. 4). The calculation of the outputs mean error of different models showed that none of the models have a suitable estimation of precipitation values in research domain. The HadRM3P model shows the lowest RMSE relative to observational data for the maximum temperature across Iran except the central parts. However, for the minimum temperature RegCM4.1 model shows the lowest difference with comparison with observation data in most parts of the research domain. For annual precipitation using the Box-Whisker plot, we can compare the correlation coefficients between the observed data and the corresponding cells in the northern and southern parts of Iran. According to the results, none of the models have an accurate estimate of precipitation in Iran (Fig. 8a). This plot for different models showed that the outputs of the HadRM3P and RegCM4.1 models have more than 0.8 correlation coefficien for maximum and minimum temperatures in most cells, respectively, (Fig. 8b and c).

Conclusion

The correlation of rainfall data shows that most models in the central and mountainous regions of Iran do not have high correlation coefficient with observational data. Spatial distribution of correlation between maximum temperature model outputs and observational data in Iran shows that the two HadRM3P and RCA4-WAS0.44 models have a strong correlation coefficient. The results also show that changes in the correlation coefficient in the HadRM3P model are low in both the northern and the southern parts of Iran. The RegCM4.1 model had the stronger correlation in the northern half in comparison with the southern parts of Iran. Also, the mean difference of estimated model output with observation data of this variable in the whole of Iran is less than 1°C and this model is the most appropriate model among the available models for minimum temperature in Iran.

Keywords: downscaling, CORDEX, Regional Climate Model (RCM), Iran.

Flood Risk Assessment Using Multi-Criteria Decision Making Based on Dempster-Shafer Intuitive Reasoning (Case Study: Nekarood Basin)

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Extended Abstract

Introduction
Among the natural disasters, flooding can cause heavy losses on the agriculture, fishery, housing and infrastructures. It strongly affects the economic and social activities. The use of modern science, especially remote sensing and GIS techniques helps the planners to assess the risk map of natural hazards such as floods for a region in the least possible time. Multi-Criteria Decision Analysis (MCDA) provides methods and techniques to analyze complex decision problems which often includes non-comparable data and metrics. Nekarood watershed with its special properties is prone to serious and devastating floods. The aim of this study is to assess the risk map of flooding in Nekarood Basin using multi-criteria decision and based on intuitive reasoning.

Materials and Methods
According to the expert opinion, the two sets of effective criteria on flood risk and vulnerability has been used for the study area. Hydro-climatologic, topographic, land cover and geological factors as effective criteria on flood risk and population density are evaluated by remote sensing techniques in this study area. Primary data used in this study are digital elevation model, Satellite images of LANDSAT 8 for different months of 2016 to 2014 to provide vegetation maps, land use map, geological map, iso-rain, road network and waterways network, demographic statistics and information related to agriculture lands and gardens. To evaluate uncertainties in the expert's opinions about the importance of different criteria on flood risk, we used intuitive reasoning theory and Dempster-Shafer model. Then, we have made flood risk map by using the multi-criteria decision method. Using the mean and standard deviation, risk map was normalized for the study area and was classified into five classes; very low, low, medium, high and very high. Finally, the state of sub-basins and land uses was assessed, compared and analyzed in terms of risk.

Results and Discussion
The results show that topographic factors and population density have the highest degree of

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importance on risk and vulnerability. To prepare flood risk map for the study area, the number 0.701 was considered for weight of risk factors and 0.299 for vulnerability weight. The results of the different risk classes show that downstream sub-basin of Neka watershed contains the high and very high risk classes and upstream Neka include the lowest area of high and very high risk classes. Generally, 87 percent of high and very high-risk areas are in downstream sub-basin of Neka. For dense forest, poor forest and rangeland, the area of low and very low risk classes is greater than that of high and very high risk classes. However, in agriculture land uses the area proportion of high and very high risk classes are more than that of low and very low risk classes. Results indicate that 59% of the land use of Nekarood watershed is located in high and very high risk classes. Neka city is located in very high risk class while 90% of Neka city is located in high and very high classes. Nekarood River, with a considerable amount of water discharge, passes through the city of Neka. The river is flowing through mountainous channel, steep slopes and high altitude areas. This volume of water is flowing across Neka city through a single channel and finally discharges into the Caspian Sea. Since this channel has limited capacity during flood time, the flow submerges the channel banks and consequently leads to dangerous floods.

Conclusion

The results indicate that the use of new technologies such as remote sensing and GIS for mapping natural disasters such as flood risk is very efficient and useful. It was revealed that using multi-criteria decision making based on intuitive reasoning is very useful to assess flood risk of Nekarood watershed. The use of this model is possible by using many criteria, the degree of hazard, vulnerability and risk for the study area. Neka city due to its particular position has very high potential for flood risk and vulnerability. The results indicate the necessity that the managers and planners have to pay special attention in various agencies to flooding.

Keywords: risk, flood, multi-criteria decision, intuitive reasoning, Nekarood.

Evaluation and Comparison of Global Ensemble Prediction Systems for Probabilistic Forecasting of Heavy Rainfalls (Case Study: Kan Basin, Iran)

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Extended Abstract

Introduction

Heavy rainfalls in small basins can lead to devastating flash flood with fatalities and tremendous damages. Thus, forecasting of heavy rainfall is an important step in development of a flood warning system. Various models were used for rainfall forecasting such as artificial neural network (Moustris et al. 2011), time series models (Sapmson et al, 2013), wavelet theory (Partal and Kişi, 2007), and regression tree model (Fallahi et al, 2011). In recent decades, the Numerical Weather Prediction (NWP) models were widely applied for weather prediction. Numerical weather predictions (NWPs) usually have uncertainties in initial conditions and model structures. In recent decades, Ensemble Prediction Systems (EPS) have been increasingly used to capture the uncertainties in NWPs. Several operational centers, including the European Centre for Medium-Range Weather Forecasts (ECMWF), the National Centers for Environmental Prediction (NCEP), the Japan Meteorological Agency (JMA), and the United Kingdom Meteorological Office (UKMO) offer valuable operational numerical predictions at a global scale (Hsiao et al, 2013).

The purpose of the present study is the comparison of the ECMWF, UKMO, and NCEP global ensemble prediction systems for forecasting of heavy rainfalls in Kan watershed, Tehran, Iran.

Materials and Methods

In this paper, the performance of the global ensemble prediction models has been evaluated for heavy rainfall forecasting in Kan Basin, Tehran, Iran. This research was conducted for 8 heavy rainfalls (flood producer) in the study area using two different precipitation thresholds including

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5 and 10 mm. For this purpose, the UKMO, NCEP and ECMWF ensemble predictions are archived in the TIGGE database. Other forecast centers were not used in this study for various reasons, such as the unavailability ensemble forecasts of some centers in 0000 UTC. It is worth noting that interpolated predictions on 0.125 degree resolution were used in this study.
Then, the heavy rainfalls predicted by UKMO, NCEP and ECMWF were compared with the observed rainfall. Three criteria including the accuracy, reliability and sharpness were applied to assess the predictive efficiency of ensemble forecasters. The Brier Score, reliability diagram and average width of 50% and 90% prediction intervals were respectively used to assess the three mentioned criteria.

The Brier score is widely applied in meteorology to assess the probability and ensemble forecasts. This score is presented as following equation:

$$BS = \frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2 \quad (2)$$

In the above equation, P_i is the forecast probability of the event, O_i is the observational value equal to 1 or 0 depending on whether the event occurred or not, and N is the number of forecast-observation pairs. A minimum Brier score is equal to zero for a perfect forecaster.

Reliability diagrams are a graph of the observed frequency plotted against the forecast probability of the event. For perfect reliability, the forecast probability and the frequency of event is equal. Thus, the closer the reliability curve to the diameter is the higher the reliability.
Sharpness is a feature of the forecasts that refers to the concentration of the predictive distributions.

The more concentrated the predictive distributions are, the sharper the forecasts and thus the better the predictive model.

Results and Discussion

The results showed that for 5 and 10 mm rainfall thresholds, UKMO's ensembles were the least efficient, reliable and sharp. Thus, UKMO's ensembles are not suitable for heavy rainfall forecasting in the study area. It was also observed that for 5 mm rainfall threshold, there was not a significant difference between the accuracy and reliability of NCEP and ECMWF ensembles but with increasing the level of threshold to 10 mm, NCEP's ensembles had higher efficiency and were more reliable. In terms of sharpness, NCEP's ensembles were also the most sharp, followed by ECMWF and UKMO.

Conclusion

Since the higher threshold is necessary for heavy rainfall prediction, so the 10 mm rainfall threshold was used in assessment of the predictions by the criteria. Analysis of the results based on the three mentioned criteria showed that NCEP's ensembles had the best performance compared with the other predictions. Therefore, it is recommended to study the NCEP's ensembles for prediction of heavy and flood producing rainfalls in mountainous watersheds like Kan Basin.

Keywords: Ensemble Prediction Systems (EPS), heavy rainfall, Kan Basin, uncertainty.