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# The effects of spatial patterns of urban green structure on the thermal changes of urban heat islands: The case study of Tehran

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## Expanded Abstract

### Introduction

Urbanization, especially in big cities of developing and developed countries, has major impacts on climate change by producing greenhouse gas and increasing average temperature, and thus creating urban heat islands (UHI).

Rising temperature and global warming intensify a wide range of negative environmental and social consequences, including social welfare, public health, and natural sustainability. Urban heat islands describe the phenomenon of higher temperatures in urban areas than in rural and suburban areas, so that as urbanization increases, the effects of urban heat islands are intensified.

One of the contemporary approaches to reduce the effects of urban heat islands is to increase air quality through green infrastructure. The term urban green infrastructure (GI) refers to the planned networks of natural and semi-natural environments with a wide range of ecosystem services in urban areas at different spatial. In addition to reducing the effects of urban heat islands by the quality and quantity of green spaces, it is stated that green infrastructure can be helpful to manage runoff water controlling flood, also improving urban beauty, and protecting biodiversity.

The unplanned urban development and even planned ones with the least attention given to green land uses (both natural and built) are the main factors responsible for destruction of natural ecosystems and thus increasing warming conditions especially in metropolitan areas, where the growing the built areas destroy the landscape pattern of natural and green areas. Lack of enough attention to preserving natural and green infrastructure is one of the factors causes city warming. Urban heat islands challenges are important issues in urban environmental planning nowadays. Urban heat island consists of air temperature and surface temperature. Studies show that land cover planning and management can control surface temperature. The relationship between increasing the green spaces as an important element of the green infrastructure and decreasing surface temperature is already has been studied. Regarding the literature has been reviewed in this paper, the purpose of this study is to investigate and clarify the detailed relationship between the characteristics of spatial patterns of urban green spaces and their influences on surface temperature. Spatial composition and spatial configuration are two main elements of spatial patterns of urban green areas. Classification of green land cover based on Local Climate Zone (LCZ) helps to discover the detailed relationship between each patterns' components and the classified green spaces. The case under study is the city of Tehran, which has witnessed certain changes in relation to the development of built-up areas (both in form of planned and unplanned developments), reduction of green spaces and their spatial patterns, as well as rising average temperature.

### Materials and Methods

Although different methods have been applied in the research to classify the green land uses, they have mostly used the same classification for urban green space. However, these types of green space have not been

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considered as a means of reducing the surface temperature. Due to ability of measuring different green landscape patterns in a period of time, this study based on a conceptual model of the relationship between green spaces criteria of spatial composition (surface area and proportion of green space) and spatial configuration (sequence or physical distribution of different types of green spaces) to find their relation to urban heat island.

Tehran, the case under study, is located in the southern hills of the Alborz Mountains and the northern edge of the central desert of Iran, which covers an area of about 730 km<sup>2</sup>. Its ecological landscape shows a long-term shaping influencing by climate, geology and other natural factors and therefore different landscape pattern from north to south exists in the city. Uneven urban developments cause damages to the natural ecosystem and terminate the structure and function of landscape patterns, intensifying conservative policies in protecting natural conditions and preventing the process of land degradation (vegetation, natural corridors and open natural spaces, etc.) are essential for the city natural and built environments.

In the process of investigating the relationship between urban spatial patterns of greenspaces in city of Tehran and land surface temperature, different methods and techniques are applied. The greenspace classification map of the city of Tehran was produced with the help of Landsat 8 satellite (2019) and LCZ method of land use classification, which divides green areas into four classes as follows:

A) heavily wooded landscape of deciduous and/or evergreen trees, land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.

B) Lightly wooded landscape of deciduous and/or evergreen trees, land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.

C) Open arrangement of bushes, shrubs, and short, woody trees, land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.

D) Featureless landscape of grass or herbaceous plants/crops, few or no trees. Zone function is natural grassland, agriculture, or urban park.

Kappa coefficient and overall accuracy of this map was 0.8706%, 88.172%, which confirms its accuracy. The next step was selecting landscape metrics. Based on the aim of the study and the reviewed literature, spatial composition and spatial configuration are selected as two main elements of spatial patterns of urban green areas. The relationship between land cover patterns and surface temperature is analyzed and discussed by using Pearson and Pearson Partial correlation method.

## Discussion of results

The result of Pearson correlation analysis showed that there is a significant and negative correlation between spatial composition of A, B and D land cover classes with surface temperature. The highest negative correlation belongs to class B (scattered trees) and the lowest belongs to class A (dense trees). In contrast to these negative correlations, the correlation coefficient of class C with surface temperature is positive and significant.

The result of Pearson correlation analysis regarding spatial configuration showed that the average size of each green space class has a continuous and significant negative relationship with the surface temperature, though the size of these correlations varies in different classes. The correlation also showed that besides size and significance, the direction of green marginal density of each class also differs. It should be noted that the surface area of green space classes (as a composition metric) has a great impact on the results so that the correct and clear correlation of configuration metrics with temperature could not be distinguished. This issue was resolved by using Partial Pearson correlation coefficient and controlling the effect of Class Area metric. As a result, the relationship between configuration metrics and LST changed significantly. Before controlling the Class Area metric, almost all metrics were correlated with LST, however, the new detailed findings showed that only the Mean Size of Patches in A and D classes and Edge Density in B and C classes had a significant relationship with surface temperature.

The study shows that spatial composition of green spaces in Tehran in relation to the Class area of classes A, B and D had a negative and inverse relationship with surface temperature. Class B, located in the east and west of Tehran, has the highest negative correlation. Class A, in the east and center of the city with the lowest surface area and its scattered distribution pattern in comparison to other classes, has the least negative correlation with surface temperature (95% confidence level). Class D, located mostly in the south and west of the city, has a negative relationship between class area and temperature at the 99% confidence level. The correlation of spatial composition of class C in the northern half of the city is not like the other three classes and indicates a positive and significant relationship with surface temperature due to the presence of shrubs and grasslands with low density, scattered shrubs, and soil.

Regarding the partial Pearson correlation of spatial configuration metrics, the Mean Patch size of Class A at 99% confidence level shows a negative and significant relationship with temperature, but due to its subdivision and uneven distribution of green space in this class, the effect of this class in the reduction of temperature is not

significant. The Mean Patch size of class D has a significant negative relationship with surface temperature at 95% confidence level, although its cooling effect is not considerable.

Both Edge Densities of classes B and C at 95% confidence level had a significant positive correlation with surface temperature, but as trees did not exist in a dominant and dense manner to cause shading and temperature adjustment in these type of greenspace classes, a positive correlation between the Edge Density of them and surface temperature is occurred.

## Conclusion

This paper has demonstrated the relationship between urban heat islands and spatial patterns of green spaces in Tehran city. The literature based study showed the scope of the problem explaining that urban greenspaces contribute to mitigate climate change impacts through decreasing the surface temperature. The spatial form and pattern of urban green spaces have different effect on surface temperature as indicated in several studies. Importantly, planners and designers need more detailed studies to take into account the relation between effects of spatial composition and configuration of different classification of plants in Tehran and the needs for the development for built areas to have a control on urban surface temperature. In this research, greenspaces patterns were studied using Local Climate Zone (LCZ) method and correlation of spatial pattern (composition and configuration) of each of LCZ green classes with the surface temperature were provided. The results of the analysis of the spatial composition of these classes showed that tree canopy greenspaces in both cases of high/low density and low plants have a reducing effect on temperature, but low-density grasslands and scattered shrubs with soil cover have a positive relationship with temperature. More detailed results on the spatial configuration show that only the mean patch size in dense tree areas and low plants has a significant negative correlation with temperature. Nevertheless, Edge density of scattered trees and open arrangement of bushes had a significant positive relationship with temperature. Thus, urban green space planning and management, through determining the type, composition, and configuration of existing patterns and their improvements based on their effect on the reduction of surface temperature will help to decrease urban heat island impacts.

Based on the findings, in order to reduce the average temperature of the city of Tehran, it is recommended to increase the area of class B greenspaces in the central part of Tehran. In addition, changing the green space of class C to one of the classes A (if possible) or B will reduce the surface temperature and improve the thermal comfort.

**Keywords:** heat islands, spatial pattern, structure of urban greenspace, Tehran.

## Place development and environmental quality improvement of urban walk with a grounded theory approach (Case study: Hamadan Buali Urban Walk)

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### Expanded Abstract

#### Introduction

The public spaces of the city, as an important part of the city's social identity, constitute the area of social interaction and activities of citizens. When it comes to urban space, it is actually a space that provides economic, social and cultural interactions to its users. One of the most important criteria to be considered in evaluating cities and urban environments is the quality of public areas in that city. The inevitable fact is that the quality of these spaces is a measure of the utility of cities. Urban public spaces allow people to meet and interact with one another. What drives people into one space is the presence of other people. Creating sociable public spaces as a place for social interaction to create sustainable urban environments is one of the goals that have received much attention in recent decades. The main function of public space is to provide for the presence of the people, so its social and cultural dimensions are of particular importance.

Nowadays, due to many problems such as the car's dominance in space, decreased safety, reduced security, lack of diverse and attractive population, citizens' satisfaction with space and consequently their desire to be present in these spaces has been reduced to transform public spaces of the city, which should be the basis of social interactions of different age groups and behaviors, and to become passable spaces.

Urban walks are also one of the most important public areas in cities where more attention is paid to human needs and if they have the necessary qualities, they can be successful in attracting people and providing a suitable environment for increasing attendance and social interaction.

In this study, we tried to explain the model of development and improvement of environmental quality of urban pedestrian spaces in Hamadan Bu-Ali Street. Since the environmental quality of pedestrian spaces has a direct impact on the quality of life and environmental health of space users, therefore, attention is paid to the contextual and different characteristics of each space in the process of environmental quality enhancement, as well as the feedback and participation of users of the desired spaces and improve the environmental quality of urban spaces.

#### Materials and Methods

The stages of a grounded theory research are based on data collection, note-taking, coding, categorization of concepts and categories. In the open coding process, the researcher forms data on the phenomenon under study through data fragmentation and, based on the data gathered from interviews, observes daily notes. The technical notes specify the main and sub-categories. Then, at the axial coding stage, the researcher selects an open coding category and examines it as the main category or phenomenon at the center of the process. Then, the relationship between other categories in consist of causal conditions (factors that influence the main category), strategies (actions taken in relation to the main category), contextual and intermediate conditions (environmental and contextual factors). Specificity that influences strategy and consequences (consequences of strategies) are identified and deduced by a central issue.

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In this way, we first saturated the in-depth interviews with 60 snowballing professionals, including professionals, city managers, business people, users and tourists familiar with Bu-Ali Street. Theoretical saturation with the snowball method is achieved when no new study sample is added to previous studies and nothing new is achieved. Participants in these in-depth interviews were divided into two categories of participants with internal origin (residents, business and urban managers) and participants with external origin (specialists, tourists, and customers). In-depth semi-structured interviews were conducted based on research questions. Subsequently, notes were taken and coded. The process of analyzing data as encoding is that in open coding the data is labeled and conceptualized and then categorized. In axial coding, the purpose is to identify a phenomenon with regard to the conditions that lead to it, and that is the context in which the category is located, generally the axial coding, the process of associating the subcategories. Into one category. Selective coding is the process of selecting one category for the central category and linking all other categories to that central category.

#### Step One: Open Coding

In this type of coding, concepts are formed after summarizing the interviews and examining the similarities and differences. During open coding, data is crushed, analyzed, compared, labeled and conceptualized. Conceptualization means that every part of the interactions, ideas and ideas contained in the text is extracted.

#### Step Two: Axial Coding

The purpose of this step is to establish relationships between concepts generated in the open coding process. The basis of the relational process of axial coding is to focus on and designate one category as the central category and then place other sub-homogeneous categories under the main category. Then, by examining the concepts and placement of close and homogeneous concepts in one class, the central category is extracted. 603 codes were extracted from the encoded data. These codes were coded at the open coding stage in 136 concepts and then 33 main categories. The categories extracted according to the Strauss and Corbin model were discussed in four sections: conditions (causal, contextual, confounder), main categories, strategies and outcomes.

## Discussion of results

The results show that environmental quality promotion can provide all aspects of tourism, social, cultural, economic, functional, physical and managerial development of Bu-Ali urban walk development with strategic approach to the issue of location development. The core of the paradigm research model is a combination of programmable spatial identities and the ability to develop an urban walk that are influenced by spatial assets and spatial quality. Therefore, spatial identity and presence can organize as a driver for sustainable development and mitigation of existing anomalies, including diminished location, high commercialization and extreme and reduced environmental, functional and physical values. This model of location development has been extracted and deduced from the interaction of internal location factors and spatial and environmental capabilities. Considering the involvement of all stakeholders in the process of environmental quality development of the pavement, the use of indigenous and collective knowledge instead of engineering and expert knowledge, cultural and capacity building, interactive processes rather than top-down processes and the identification of internal assets in interaction with the local community, The concepts were extracted and coded in this study. Thus, the pavement spatial development model is based on identifying internal assets, leveraging them, and ultimately managing the place that is shaped and guided by a collaboration between local knowledge and expert knowledge.

## Conclusions

Tourism, commercial and cultural identities are formed on the basis of location assets and are influenced by the culture and history of the place and the economic and commercial implications of the process of interaction between actors. That is, enhancing tourism, commercial and medical identity of the pavement, event making, enhancing social flow in space, pedestrian spatial networking based on cultural, recreational and tourism functions, upgrading tourism support services, formulation of promotion criteria and street views, the traditional recreation and restoration approach, the refurbishment approach rather than the renovation approach, etc. are strategies and measures that can help sustainably develop and enhance the environmental quality of pedestrian spaces. The output of this process will create a dynamic, engaging, motivational, readable and motivating atmosphere of curiosity in the minds of the pedestrian location that provides the potential for competitors to attract audiences and tourists. This image creates an added value based on historical and cultural conditions as well as the development of environmental quality by increasing the visibility on the urban walk. In this way, we will see tourism growth, investment incentives, functional refinement around cultural and recreational functions, physical recreation, revitalization, empowerment and participation of indigenous actors, and ultimately promotion of place culture.

**Keywords:** environmental quality, Hamadan, pedestrian of Bu-Ali, presence, urban pedestrians.

## Investigating the trend of changes in water area of Shadegan wetland and its relation to drought occurrence hydrology and sugarcane drainage water ((Jarahi watershed)

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### Extended Abstract

#### Introduction

Shadegan International Wetland is one of the largest wetlands in the country, which was included in the list of international wetlands of the Ramsar Convention in August 1975. This wetland is very important with its great biodiversity and various functions such as flood control, air conditioning, soil erosion control and livelihood of a part of human communities. Wetlands ecosystems play an important role in the ecosystem in arid and semiarid regions. Drying these ecosystems can be caused by human and natural factors; Meteorological droughts are caused by natural factors such as precipitation and temperature rise and evaporation, but in the event of hydrological drought, despite the above factors, human factors in water management play a key role. Climate change and ongoing droughts with rising temperatures and evaporation and declining humidity and runoff in catchments and by human intervention through the construction of dams and large irrigation networks, the entry of agricultural wastewater, industrial and urban pollution and the oil ecosystem have made it difficult for wetlands.

The trend of climate change and the occurrence of continuous droughts with increasing temperature and evaporation and decreasing humidity and runoff in catchments, especially in the catchment area of wetlands located in arid and semi-arid regions, like Shadegan, and due to human intervention, ecosystems have caused wetlands problems and caused them irreparable damage. The purpose of this article is to monitor the wetland surface area of the wetland over a period of 30 years. The relationship between the occurrence of hydrological drought and the water area of the wetland and the calculation of the drainage water entering the wetland and its relationship with the water area of the wetland are the objectives of this article. The results of this paper will help water resource management decision makers to provide both wetland water supply from the Jarahi River freshwater source and integrated sugarcane drainage potential with respect to its treatment as an opportunity to save the wetland as an ecosystem. Live help with multiple functions.

#### Materials and Methods

In order to investigate the relationship between hydrological drought and its role on Shadegan wetland changes, Streamflow Drought Index (SDI) was used. For Jarahi basin with 10 stations, has a 30-year period. Hydrological drought characteristics including the frequency of continuity and magnitude were calculated and analyzed for decades for the catchment area of the wetland. To calculate the duration of the drought, the year of occurrence was calculated as the first year and its continuation until the conditions became positive. Drought magnitude is obtained from the positive sum of droughts in each decade

Landsat TM and ETM + and OLI satellite images were used in the years 1988 to 2017 in June. Three stages of preprocessing, processing, and post-processing on images are carried out and to categorization use of Supervised Vector Machine (SVM). The images were classified into three classes of water, vegetation, and no cover or soil. In order to evaluate the classification accuracy of classified images, two indicators, total accuracy and kappa

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were calculated. Changes in Discharge The Shadegan hydrometric station were calculated as the last entry point of the Surgical river to the wetland and other water sources entering to Shadegan wetland, whose discharge was measurable and available, such as sugar cane drainage water. Their values were compared with changes in wetland area water. Data's related to discharge from other sources of water entering to wetland, which was caused by sugarcane drains, was received in millions of cubic meters and converted to cubic meters per second, so that with the data's of discharge, the last entry point to Shadegan wetland from Jarahi River and be consistent. The water area of the wetland was compared and analyzed with hydrological drought. Then, its relationship with the inflow to the wetland was identified and analyzed, and the role of the inflow of sugarcane in increasing the water area of the wetland was revealed.

## Results and Discussion

Naturally, the most important source of water for wetlands is seasonal and permanent rivers and runoff from the watersheds leading to them. The frequency of occurrence, persistence and magnitude of drought in the watershed area of the wetland leads to a decrease in freshwater inflow to the wetland. Meteorological drought, especially in the last decade, and the development of irrigation networks and the construction of dams have been the main reasons for the occurrence of hydrological drought in the watershed, resulting changes in the water level of Shadegan wetland. The frequency of hydrological droughts of the decade in the watershed of Shadegan wetland has been increasing and in the last decade the drought storm has reached 8 to 9 event. The persistence of hydrological droughts in the basin has an increasing trend, although there is no continuity in the first decade, but in the second decade in most stations the continuity is three years and in the third period the drought is 8 years. At Shadegan station, which is the last water entry station to the lagoon, the continuity has reached 9 years. The study of the large size of the hydrological drought of the decade in the watershed of Shadegan in the first and second decades was low, but in the third decade the magnitude of the drought reached more than 8, which indicates the persistence and pervasiveness of the drought in the third decade.

The trend of 30-year changes in the water area of Shadegan wetland is increasing. Prior to the arrival of the drainage system due to sugarcane projects, the highest water area of the wetland was 22.4%, which was due to the conditions of the watershed related to the wetland facing severe wet conditions. In 2005, the wetland's water area reached its maximum value during the 30-year period under surveillance; in the previous year, 240 million m<sup>3</sup> of Drainage water entered the wetland from sugarcane projects, and this year 266 million m<sup>3</sup> of Drainage water entered the wetland. In addition, mild wetland conditions have prevailed in the watershed this year. Therefore, the water area of the wetland in the early years was subject to precipitation conditions in the wetland watershed and since the year that sugarcane drainage entered the water of the wetland, it has been subject to precipitation conditions and the volume of incoming drainage water from sugarcane projects.

## Conclusions

Naturally, the most important source of water supply for wetlands is seasonal and permanent rivers and runoff leading to them. Frequency of occurrence, persistence and magnitude of drought in the catchment area of the wetland lead to a decrease in fresh water entering the wetland. Meteorological drought, especially in the last decade and the development of irrigation networks and construction of dams and earth dams have been the most important reasons for hydrological drought in the catchment area and as a result of changes in water level of Shadegan wetland (Dargahian et al., 1397). Drought is an integral part of the nature of Iran, especially the arid and semi-arid region, including the study area. The whole basin has been facing the longest drought cycle. The results showed that although the frequency of drought persistence and magnitude increased in recent decades compared with other decades, the area of wetland water has increased trend. The area of the wetland in the last decade has not been consistent with the discharge exit from the last hydro meteorological station of Shadegan, but has been associated with the total amount of water entering the sugar cane and discharge Shadegan hydro meteorological station. Therefore, sugarcane Drainage water, regardless of its quality, has played a key role in the recovery of the Shadegan wetland as a living ecosystem in recent decades, due to the severity and severity of drought.

**Keywords:** hydrological drought, Jarahi river, sugarcane Drainage, wetland ecosystem.

# Monitoring and modeling of Urmia lake area variations using Artificial Neural Network

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## Expanded Abstract

### Introduction

Due to increase of water exploitation and drought, the need for water resources has been risen in past decades. Numerous regions around the world are under threat of environmental crisis, as a result of climate change. Declination in the amount of precipitation can be led to various subsequences, such as significant reduction in the level of ground and surface water, e.g., lakes. Through the development of satellite imagery systems, it is possible to monitor and evaluate changes in rainfall, groundwater level, surface water area, and level.

Urmia Lake is one of the largest hypersaline lakes in the world and the largest inland body of salt water in northwest of Iran. The lake and its corresponding basin were in a catastrophic situation and under threat of drying up. The lake's area and WL were decreasing from 1995 due to climatic change and anthropogenic activities. Irrigation expansion after 2000 was indicated as the dominant human driver of the Lake Urmia desiccation.

Remote sensing provides certain tools for monitoring lakes and their basin over time and space. Numerous studies have been conducted to observe and evaluate climate change after the launch of Gravity Recovery and Climate Experiment (GRACE) satellite mission. GRACE dataset has been used widely to determine water storage variations over the world as well as Iran. This satellite data has been used for various purposes including ground and surface water monitoring. Employing this dataset beside precipitation and satellite altimetry data have been used for observing changes in watersheds and lakes in numerous studies. Modelling and predicting environmental and climate changes are always an important task. Gathering several remote sensing data and predicting them would be helpful mostly for disaster management and also decision making.

Therefore, it is possible to observe and evaluate variation in rainfall, groundwater level, surface water area, and level. In this study, Urmia Lake and its watershed changes were monitored using various satellite data such as TRMM, GLDAS, GRACE, MODIS. Moreover, machine-learning based methods were developed to predict the lake surface changes.

### Materials and Methods

To monitor Urmia Lake changes, several data were used to survey variation in precipitation, ground and surface water storage, lake water level, and area in 183 months from April 2002 to June 2017. Sufficient temporal resolution of the data is an essential factor in monitoring of changes through the time. Accordingly, for monitoring the overall change of the Urmia lake, we prefer a satellite data with at least monthly temporal resolution. Therefore, overall variations of the lake and its corresponding basin were modeled using these data with adequate temporal resolution.

Tropical Rainfall Measuring Mission (TRMM) is an international collaboration which aims to observe rainfall for environmental studies. TRMM data provides precipitation in various temporal and spatial resolutions. In this study, TRMM-3b43 level 3 monthly data, with 0.25 degree spatial resolution estimates rainfall in Urmia lake basin, including 83 pixels in each time step.

The GLDAS hydrological model consists of various variables (e.g., soil temperature, soil moisture, precipitation, etc.). In this study, the GLDAS data with 1 degree spatial resolution provides terrestrial water storage (TWS) by integrating soil moisture ( $\text{kg m}^{-2}$ ), snow water equivalent ( $\text{kg m}^{-2}$ ), and canopy water storage ( $\text{kg m}^{-2}$ ). Three types of monthly GLDAS model data (MOS, VIC, and NOAH) were hired for this purpose.

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GRACE is a joint mission between Germany and the USA, giving information about mass changes within Earth. The level 2 (RL05) data was of GRACE used to monitor TWSA, which was computed from spherical harmonics using methods developed by Wahr and Swanson. In addition, a 300 km Gaussian filter was applied to reduce high frequency noises.

The investigated Global Reservoirs and Lakes Monitor (G-REALM) dataset including Jason-1, Jason-2/OSTM, and Jason-3 altimeters were employed to survey Water Level (WL) variation of Urmia lake.

In order to monitor lake extent changes during the 17 years, MODIS atmospheric corrected product MOD09Q1 version 6 data, with 250 m spatial and 8-day temporal resolution was used through Google Earth Engine. The product provides surface spectral reflectance of bands 1 and 2, which is the composite of 8 products with the absence of clouds, cloud shadow, and aerosol loading. Although, the Normalized Difference Water Index (NDWI) is a common method to separate water from land and it also had the best result on Landsat data, Normalized Difference Vegetation Index (NDVI) performs transcendent distinguishing between water and land while using MODIS data and also in the specific case of Urmia Lake. Therefore, in this study, the NDVI index was chosen as an appropriate index to separate water and non-water. To determine lake area, first, water region was detected. Then, area of water extent was computed as lake area.

For modeling the lake's area variation, machine learning based methods were investigated. As a time-series prediction problem, a Multilayer Perceptron (MLP) and a Long Short-Term Memory (LSTM) networks were constructed using TRMM rainfall, GLDAS, GRACE TWS, and altimeter WL as inputs (predictors) of the models, and lake's area as Target. About 80% of data was assigned to training, 10% to validation, and the same portion to test. A feedforward MLP including one hidden layer and 5 neurons and a Recurrent LSTM network with same hidden layer and 10 neurons, were obtained. In order to evaluate network's performance, Root Mean Square Error (RMSE) was used. In addition, the delay parameter of 12 months or one year was chosen for estimating future variations.

## Discussion of Results

Except seasonal changes, amount of monthly rainfall during the mentioned period experienced a significant decrease from 2004 to 2008, and then it fluctuates to 2017. The changes in precipitation rate can affect other parameters considerably. As a result, water mass variation obtained from GLDAS data, falls from 2003 to 2008, and after that, similarly to rainfall variation, it fluctuates. However, TWSA computed by GRACE data, after reduction to 2008 and rise to 2010, behaved otherwise, and it went down steadily to 2017. Urmia Lake WL declined during the whole period. This decrement was intensified from 2006 to 2010, after that it halted gradually to 2017 as consequence of increase in rainfall rate. Area of the lake decreased from 2004 to 2015, also it faced an extreme fall in 2008. Next, to 2017, the area increased slightly.

Due to a decade drought of Urmia Lake, it was in critical circumstance. Consequently, estimating future variation of the lake is necessary. Instead of using physical models or assessing the impact of each parameter on the surface of the lake directly and indirectly, which are complicated tasks, a machine-learning based method is hired. Disregarding the exact relation between factors, this learning-based method can determine and model changes. By using two of the most common ANN based methods including MLP and LSTM, variation of the lake during that period was modeled.

MLP and LSTM models reached overall RMSE (for normalized data) of 0.0586 and 0.0511, respectively, which indicates reliability of both models for predicting lake area changes; however, LSTM network performed superior specially over test data (RMSE of 0.0487). In addition, to predict Urmia Lake's further changes and assess LSTM model capabilities comprehensively, four networks were constructed to predict lake area of next 3, 6, 9, and 12 months. Accordingly, result demonstrates LSTM abilities for predicting upcoming year variation of the lake with RMSE of 0.0882 (better than prediction for 6 and 9 months).

## Conclusions

Variation in each part of environment and climate (such as rainfall, TWS, WL and area of lakes) affects others. Therefore, it is possible to monitor and model these relations between the parameters. In this study, two ANN methods of MLP and LSTM were investigated to model Urmia Lake surface area which the LSTM model performed transcendent. Moreover, LSTM method provides a model which is able to predict the lake area of next 12 months with a high accuracy.

In order to improve the network's accuracy, it is suggested to increase the number of data and parameters, which are used as network input. It would help the network to implement the training stage with a higher capability to recognize diverse situations properly.

**Keywords:** ANN, neural network, prediction, Urmia Lake, water level.

## Cooling the urban environments and its impact on climate change in informal settlements through outdoor thermal comfort (Case studies: Aa'melli, Ghaleh Sakhteman and Hojjat neighborhoods of Mashhad)

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### Expanded Abstract

#### Introduction

The climate becomes warmer than ever before, as evidenced by numerous observations and modeling that has in turn created a warming climate in cities. Therefore, various climate change projects and attention to heatwaves in recent centuries have been considered. Moreover, the increase in population and its activities in various fields have caused problems such as heatwaves around the world. In addition, changing the pattern of occurrence of these changes and their unpredictability have led to an increase in the number of them in cities and to reduce concerns and adapt to these risks in various aspects of urban life, especially human health, to create sustainable urban forms. This phenomenon has caused the death of thousands of people in the world. One of the important reasons is the flaw of the cities to deal with the increase in heatwaves. While different changes and global warming can affect urban areas, urban areas can also exacerbate these changes. Rising urbanization rates and people's desire to live in cities have led to higher urban temperatures than their surroundings. Studies show that a city with a population of one million people has experienced an increase in temperature between 1 and 12 degrees. This increase in temperature is due to the structure of cities, which has many negative effects and consequences for cities; So, urban environments should be planned and designed in such a way as to improve the health of individuals and thus the presence in public spaces of cities.

Urban forms such as urban canyons and vegetation at the pedestrian level are among the factors affecting the reduction of urban temperatures in urban areas and neighborhoods. The impact of these factors on the outdoor thermal comfort of humans by few research in Iran has been considered.

A review of the research background of the subject shows that no serious attention has been paid to the native urban forms of Iran as a factor for reducing urban heat and promoting human health; However, local urban planning helps architects and planners to address urban problems by identifying needs in indoor and outdoor environments to provide the most effective way to reduce the severity of outdoor environments using all design elements. Given that there is still, no place to pay attention to how urban forms change in order to reduce the effects of climate change and outdoor thermal comfort professionally.

The present study focuses on the impact of urban forms on informal settlements and old textures on outdoor thermal comfort. The ambient air temperature and the creation of outdoor thermal comfort in the city of Mashhad, which is one of the cities that experience the most urban forms of informal settlements. The present article, first, examines the research done in the thematic field of the article and then in the next part, the theoretical framework is extracted by using articles, dissertations, and books. In the third part of this framework, simulation in Envi-met software and PET index output in Rayman software were used analysing in Leonardo to identify the effects of urban forms on air the temperature in microclimate and outdoor thermal comfort using physiological equivalent temperature index (PET). Studies conducted in the summer and on August 26, 2019, have been selected due to the high heat of the sun and its effect on creating outdoor thermal comfort in open urban spaces.

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## Materials and Methods

Due to the nature of the subject, the research method is applied and based on two parts. In the first part, the documentary method is used to formulate the theoretical framework. Thus, by referring to articles, treatises, and books by taking notes, the information needed to understand the thematic literature as well as studies conducted in the field of research have been collected and then descriptive and analytical methods are used to prepare and compile the conceptual framework of research. In the next part of the research, the case study was studied and the maps were extracted using GIS. The method of survey and harvesting of climatic information from the Mashhad Climate Organization have been used to collect climatic data. In order to identify the effects of the influential components of the urban form, the Envi-met 4 and Leonardo software collections as well as Rayman have been used. In this study, most simulations were performed in summer (August) and based on data from Mashhad Meteorological Station. This simulation was selected on August 17, 2019, and at sunrise and sunset between 6:00 AM and 8:00 PM local time due to the high temperature of the sun and its effect on ambient temperature and surfaces in open urban spaces. This simulation lasted for 156 hours for three urban forms.

## Discussion of results

The present study investigates the outdoor thermal comfort in informal settlements in Mashhad. Various studies have shown that lowering the ambient temperature in summer can reduce environmental thermal stress and thus improve outdoor thermal comfort. The results in this paper suggest that as the height-to-width (H/W) ratio increases, the sun's access to the environment decreases, and the amount of shading on the surfaces increases resulting in a decrease in ambient temperature. Therefore, it can be said that the height-to-width (H/W) ratio is inversely related to the ambient temperature, and urban form factors such as the height-to-width ratio (H/W) and its shading play an important role in reducing the ambient temperature. On the other hand, the simulations performed to show the temperature difference, so that the difference between the mean indexes (PET) during the hours of thermal stress are 0.68°C, 2.53°C and 3.27°C.

The heat stress of the Hojjat fabric is greater than that of the other two fabric and there are more hours in the absence of outdoor thermal comfort, which indicates the temperature difference in all three fabric; but the same, the difference stems from different environmental parameters in the three urban forms. One of these parameters is the coverage of outdoor surfaces and materials used in the outer shell of buildings, which is indicated by the  $T_{mrt}$  average temperature index as an important parameter in creating thermal equilibrium in the environment. Studies show that the average temperature index of radiant temperature ( $T_{mrt}$ ) is directly related to the PET index and the higher the average temperature index of radiant temperature, the higher the PET index, and vice versa; Therefore, the high average radiant temperature in the texture of Hojjat compared to the texture of the agent and the Ghale of the building in the peak hours of heat shows the high rate of heat reflection to the environment in the texture of Hojjat compared to the other two textures. Higher average radiant temperature ( $T_{mrt}$ ) in the texture of Hojjat means reflecting more heat than urban levels and can be closely related to the materials used in this texture and the amount of sun access and thus the effect of height to width ratio (H/W) on the ambient temperature, in different levels. Due to the color and texture of the brick, it absorbs less heat and gradually releases the hidden heat and its heat exchange with the environment during the night hours when the air cools down. On the other hand, the temperature a difference of 0.68°C in the first and last hours of simulation in the operating tissue shows that the use of brick materials can reduce the heat exchange with the environment and thus reduce the ambient temperature.

## Conclusions

By changing the urban forms, it is possible to reduce the temperature of surfaces and the environment in the city of Mashhad as a result of improving the outdoor thermal comfort. In this way, the heat of the urban environment is related to the temperature of the surfaces of the building walls, and the lower surface temperatures help to reduce the ambient air temperature. Therefore, covering roofs and walls with low-reflecting materials can significantly reduce urban temperatures. Microclimate surveys in three different textures show that the texture of informal settlements is different in terms of outdoor thermal comfort and this difference originates from urban forms elements, especially the materials used in buildings and roofs. Also, the presence of wind in these samples showed that the creation of wind tunnels in urban canyons against favorable urban winds can affect the ambient temperature. So, it can be said that the ambient temperature has an inverse relationship with outdoor thermal comfort; in other words, the lower the ambient temperature in summer. People's health improves with the reduction of physical and mental problems, so the elements of the urban form depend on reducing the temperature of surfaces and the environment. Therefore, the study of urban form elements in three contexts shows that although the height to width ratio (H/W) is one of the most important elements of urban form and the higher this ratio, the shading and consequently the PET index improves, without any creating shading on this

sufficient reduction. Studies show that wind can reduce temperatures. Although the high height-to-width ratio and the decrease in the sky's visibility cause shading, releasing the heat of the urban environment to the sky during the day reduces the temperature and enters the urban environment at night by lowering the ambient temperature and warming the urban environment. Therefore, it is recommended to use height-to-width ratios in different urban canyons to reduce the ambient temperature by shading and on the other hand increases access to the sky by opening access to the sky. It should be emphasized that the use of materials that have a little reflection on the environment will reduce the average radiant temperature of the surfaces.

Urban environment cooling strategies

### **Urban scales**

H/W ratio:

- The use of height-to-width ratios in future constructions, which in addition to creating shading in urban canyons, does not cause heat to be trapped during the day in urban canyons.
- The  $H/W \geq 2$  ratio is the most optimal ratio for shading and reducing the sky view factor in Mashhad; as this ratio decreases, the use of tree cover in urban canyons should increase.

Open space coverage:

- Reducing the use of impermeable surfaces such as asphalt in open spaces to create evaporation and perspiration in the environment can lead to a decrease in heat intensity.
- Dark materials trap heat inside, and using more albedo materials (bright colors) reduce the amount of heat trapped in open spaces and asphalts by creating a thermal balance in urban environments.

**Keywords:** climate change, informal settlements, outdoor thermal comfort.

## Evaluation of the climate change impacts on irrigated wheat lands rent in Iran

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### Expanded Abstract

#### Introduction

There are assessing the impact of environmental change to internalize the externality. Climate change is the environmental change that needs to evaluate the impact on various sectors in the economy. Climate change refers to the long-term variability in the behavioral pattern of the average climate measures of an area in the absence of a change in the general climate of the region. Climate change occurs when changes in Earth's climate system result in new weather patterns remaining in place for an extended time. Agriculture is a climate-sensitive sector, and climate-smart agriculture is the way forward to increase agricultural productivity sustainably. Based on the reanalyzed index of global land-ocean temperature prepared by the National Aeronautics and Space Administration combined land and ocean skin temperature represents warming approximately to 1.35°C between 1880 and 2018. The climate change fact is intensive among the Middle East countries and especially Iran. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, climate change (CC) will expand existing stresses on agricultural systems, particularly those in Asia for several reasons. Given the inevitability of the effects of climate change on the agricultural sector, the assessment of its effects can be a basis for compliance with the uncertain future conditions. Some of the research has investigated the potential impacts of climate change on agriculture crops across different geographical locations. Regarding the importance of wheat in Iran's food security, the purpose of this research is to assess the effects of climate change on wheat crops in Iran. In this way, partial goals are including:

- Determination of irrigated land rent in Iran
- Investigation the impact of climate variable on irrigated land rent in Iran
- Determination of climate change impacts on irrigated wheat lands rent in Iran.

#### Materials and Method

Because of the potential for global warming, there are widespread concerns about the impact of changing climate upon the productivity of land in farming and other sectors. The needed statistics and information were collected using secondary data. The main wheat production province in Iran are West Azarbaijan, East Azarbaijan, Ardebil, Esfahan, Ilam, Razavi Khorasan, Khuzestan, Sistan and Balouchestan, Fars, Qazvin, Kordestan, Kerman, Kermanshah, Golestan, Lorestan, Markazi, and Hamedan Province. About 70% of total wheat production is related to irrigated wheat and 30% is related to rain-fed wheat.

In recent years, the land area of irrigated wheat in recent years is about 2.2 hectares in Iran. Also, The yield of irrigated wheat is about 3.5 ton per hectare in Iran.

To accomplish the research objectives, using the panel data and Ricardian approach, the final effects of climate change on wheat rent in major provinces of the country wheat production during 2000-2015 were investigated (relation 1 to 4).

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$$Q_i = Q(K_i, E) \quad (1)$$

$$C_i = C(Q_i, W, E) \quad (2)$$

$$\pi = [P_i Q_i - C(Q_i, W, E) - PL_i L] \quad (3)$$

$$V_i = \alpha E + \beta E^2 + \delta Z + \varepsilon_i \quad (4)$$

In Equation (1) to (4), where the  $Q$  is quantity of production,  $P$  is the market price of the crop,  $L$  is land, and  $PL$  is the agricultural land value. In order to predict, the effect of climatic variables on the rent in the future of climate scenarios (A1, B1, and AB) was used. Climate change scenarios or socioeconomic scenarios are projections of future greenhouse gas emissions used by analysts to assess future vulnerability to climate change. Producing scenarios requires estimates of future population levels, economic activity, and the structure of governance, social values, and patterns of technological change.

The climate change scenarios for Iran have published by the Intergovernmental Panel on Climate Change (IPCC). Change in precipitation and Temperature will happen to 2100. Temperature and precipitation respectively increased and decreased. Based on Climate change scenarios in Iran between 2025 to 2100, change in temperature will happen one degree centigrade in 2025, 1.7-degree centigrade in 2050, 2.3 degrees centigrade in 2075, and 3 degrees centigrade in 2100. Also, precipitation will decrease by 0.9% in precipitation in 2025, 1.3% in 2050, 1.4% in 2075 and 2.5% in 2100.

Also, Iran will experience an increase of 3°C in mean temperatures and a 2.5% decline in precipitation in the next century. Also, Iran by total greenhouse gas emissions nearly 616,741 million tons of CO<sub>2</sub> is the first responsible country to climate change in the Middle East, and seventh in the world.

## Results and Discussion

The results of the fixed effect by using Generalized Least Squares (GLS) show that the fixed effect is the best model for investigating climate change impacts on irrigated wheat land rent in Iran. F-test is applied to select between the pooled model and panel model. Also, the Hausman test is applied to select between the random effect model and the fixed-effect model. The quantity of F and Hausman test is respectively 2.48 and 37.2. The result indicates that the panel model is better than the pool model. Also, the fixed-effect model is better than the random effect model to evaluate the climate variable on agricultural land rent in Iran. The quantity of JB (5.8) shows that the model has normality. However, we applied GLS to resolve the heteroskedasticity in the fixed-effect model.

Log-log is the best form of this model. First, 72 proposed variables including temperature and precipitation in spring, fall, and interaction between variable, latitude, above mean sea level and quantity of inputs were estimated by stepwise regression. Then, based on the fixed-effect model, workforce, machinery, temperature, precipitation, precipitation\* temperature, harvest precipitation, and harvest temperature are significant and R<sup>2</sup> is equal to 92%.

When precipitation increases, first agricultural land rent increases. Also, when temperature increases, agricultural land rent decreases. Besides, by 1% increasing in precipitation, agricultural land rent increases 0.98%. Also, the machinery coefficient shows that by 1% increasing in machinery, agricultural land rent increases by 0.24%. The workforce indicates when percent labor increases, agricultural land rent increases by 0.13%.

The results of the final effect of climate change on agricultural land rent using scenarios of climate change in the future years showed that climate change has a significant negative impact on wheat land rents and will lead to lower product rents in the future. So, the climate change will decrease the rent by 2.07%, 2.2%, 2.34% and 3.41% in 2025, 2050, 2075, and 2100, respectively.

## Conclusions

Based on results, the total effect of climate change on irrigated wheat land rent is negative. Regarding the decreasing irrigated wheat land rent, proposed cultivation resistant to reduced temperature and precipitation. Also, the negative impacts of climate change can decrease by the change in cropping calendar of irrigated wheat. On the other hand, regarding various climate in Iran, regional research can help to decrease the negative effect of climate change. According to results, it could be mentioned that consideration of the effects of climate change on food security and farmers needed can decrease the negative effects of climate change.

**Keywords:** climate change, Iran, irrigated wheat, panel data, ricardian approach.



## Water quality parameters of Tajan River presenting a proposed method based on blind kriging and linear regression

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### Expanded Abstract

#### Introduction

The application of kriging in the field of environment is focused on four main sections; mapping of precipitation, quantitative and qualitative status of groundwater, quantitative and qualitative evaluation of surface water and spatial forecasting of air quality.

Different types of kriging have been developed, but the most popular is ordinary kriging (OK). The most important disadvantages of OK is that it assumes the mean of modelled variables to be constant and the prediction is only based on the spatial structure of the studied points. In addition, the effect of important parameters does not take into account the estimation result, and in some cases the predicted values by OK may be out of the studied range. To overcome these problems, the universal kriging and blind kriging have been developed. Blind kriging (BK) is a more complete version of universal kriging and is based on Bayesian variable selection technique which is complicated and taken a lot of time to identify the unknown mean function.

In this research, due to the complexity of the Bayesian computation, we will combine the regression technique with blind kriging as the unknown mean function is defined by variable selection techniques being used in linear regression analysis such as forward selection, backward elimination, and step-wise regression. The residuals at the known points are calculated from the difference of the observed values and the values of the selected function. Then, the residual mean at the unknown point is solved by OK method.

Tajan River is one of the most important rivers in Mazandaran province. This permanent river is about 140 km long and originates from the mountainous area on the northern slopes of Alborz Range. Tajan River runs to the plains carrying the water from various tributaries in the mountains and then drains into the Caspian Sea. Dodangeh, Lajim, Chahardangeh and Zarem rivers are the most important branches of it. The area of Tajan River watershed in the Aldehil region (before entering the Caspian Sea) is 4700 km<sup>2</sup>. There are different land uses including agriculture, aquaculture, dam construction and industrial activities around the river. The necessity to perform a systematic study of the river water quality is, therefore, a need and of prime importance.

The objective of this study is to evaluate water quality parameters in different sites on Tajan River. This study also attempts to propose a modified kriging method, in which the unknown mean function is defined by using linear regression in order to simplify the computations of blind kriging. The proposed method and ordinary kriging were used to model the spatial variability of heavy metals and water quality index and their results were compared. This case study may be counted as an initial effort to study the spatial variability of water quality parameters, which may have many practical implications.

#### Material and Methods

The water sampling took place in spring of 2018. Sampling sites were selected based on natural conditions and accessibility to Tajan River by taking into account natural and human impacts, including river sub-branches, changes in the polluting sources such as agricultural lands, residential centers, existing industries, etc. Sampling sites were named 1 to 10 from downstream (near the Caspian Sea) to upstream (the Shahidrajae Dam). Water

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samples were collected by Nansen bottles and transferred into 1-liter bottles previously cleaned by nitric acid (0.1 N). The temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), redox potential (Eh), and turbidity (Turb) of each water sample were directly measured at the sampling points. The biochemical oxygen demand (BOD<sub>5</sub>) was determined by the Winkler Azide method and chemical oxygen demand (COD) by the dichromate reflux method. Phosphate (PO<sub>4</sub>-P) and Nitrate nitrogen (NO<sub>3</sub>-N) were analyzed by spectrophotometric method, and fecal coliform (Fcoli) were measured by multiple tube method. For measuring metals, each water sample was filtered through Whatman filter (0.45 μm) and about 5 mL of HNO<sub>3</sub> (0.1 N) was added to the samples (until pH<2). Then, the samples were stored in the refrigerator at a temperature below 2°C until being transferred to the laboratory. The measured elements included Arsenic (As), Barium (Ba), Calcium (Ca), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Thorium (Th). Metal measurements were done by inductively coupled plasma optical emission spectrometry (ICP-OES). Analysis of the samples was done based on the instructions recommended by (APHA, 2005). All mathematical and statistical computations were made using Excel 2016, SPSS 22 and ArcGIS 4.10.1. IRWQI is formed by nine selected water quality parameters namely as DO, BOD, COD, EC, PO<sub>4</sub>-P, NO<sub>3</sub>-N, Turb, Fcoli and pH. Its values range from 0 to 100 and are calculated as following:

$$IRWQI = \left( \prod_{i=1}^n I_i^{w_i} \right)^{\frac{1}{\sum w_i}} \quad (1)$$

where  $n$  is the number of parameters,  $I_i$  the index value for the  $i$ th parameter (obtained from special curves) and  $w_i$  is the weight of the  $i$ th parameter. IRWQI was calculated in all the sampling sites.

The ordinary kriging method (OK) is a linear unbiased geostatistical estimator and based on spatial correlation between sites. To indicate spatial correlation between the sampling sites, the empirical semivariogram is used as a function of distance between sampling sites. There are various models of the theoretical semivariogram in GIS system and one of these semivariograms must be selected based on the calculated errors. The prediction equation is a linear weighted combination of the form:

$$Z_{x_0} = \sum_{i=1}^n Z_{x_i} * W_i \quad (2)$$

where  $Z_{x_0}$  is the estimated value at the point  $x_0$ ,  $Z_{x_i}$  and  $W_i$  represent the observed values and calculated weight at point  $x_i$ , and  $n$  is the number of observed values. Numerous studies have reported that conventional kriging is not suitable for phenomena that are highly nonlinear in nature. So, universal kriging and blind kriging have been suggested in other research. In universal kriging, a known mean function with unknown parameters is assumed. But blind kriging has an unknown mean function which is identified from experimental data using a Bayesian variable selection technique. One of its disadvantages is the timeliness and complexity of the Bayesian technique in comparison with simple kriging techniques.

In this research, due to the complexity of the Bayesian computation, we will combine the regression technique with blind kriging as the unknown mean function is defined by variable selection techniques being used in linear regression analysis. The residuals at the known points are calculated from the difference of the observed values and the values of the selected function. Then the residual mean at the unknown point is solved by ordinary. The regression equation combining with kriging blind is written as follows:

$$\hat{y}(x) = \overbrace{\mu_0 + \mu_1 \mu_0 + \mu_2 v_2 + \dots + \mu_m v_m}^{\text{the mean function (regression)}} + \overbrace{\omega(x) \varphi^{-1}(y - V_m \hat{\mu}_m)}^{\text{the residual function (ordinary kriging)}} \quad (3)$$

Where  $\mu_0, \mu_1, \dots, \mu_m$  are regression coefficients,  $v_1, v_2, \dots, v_m$  are predictor parameters in regression,  $V_m$  is (n×n) matrix, n is the number of samples, m is the number of predictor parameters,  $\hat{\mu}_m$  is (m+1) regression coefficients vector.  $V_m \hat{\mu}_m$  is target value in n samples.

The proposed method and ordinary kriging method were applied to interpolate and predict IRWQI, Fe, Ni, Co, Th, Ba, As, Pb and Cr and their results were compared.

## Results and Discussions

IRWQI had low values in midstream (sites 5, 6 and 7) near Sari City and its value increases by moving away from the city to show an improvement in the water quality status. This is due to the effect of anthropogenic pollutants in Sari city which are negatively associated with the water quality index. The average range of pH was from 7.6 to 8.11. pH values of water samples indicated that it was slightly alkaline. The relatively higher pH in water are probably due to the presence of pollution and eutrophication status. The mean values for Eh ranged from 142 mV to 201 mV. The water of Tajan River (excepting in site 1 near the sea) is non-saline.

The mean function for each variable (IRWQI, Fe, Ni, Co, Th, Ba, As, Pb and Cr) was created by multiple linear regression. The coefficient of determination (R<sup>2</sup>) and adjusted R<sup>2</sup> were used to check regression model adequacy.

t-Test and residual analysis were used in testing the regression coefficients verifying of the applicability of the regression model. The coefficient of determination ( $R^2$ ), Coefficient of Variance (C.V.) and Root Mean Square Error (RMSE) were used to evaluate the results of the ordinary kriging and proposed method. The proposed method showed 8.8% improvement for Cr, 34 for Co, 56 for Pb, 62 for As, 44 for Ba and 169 for IRWQI. In addition, both methods for prediction of thorium and nickel were almost identical. While ordinary kriging performance was good in predicting iron and better than the proposed kriging, because for parameters whose correlation is strong with distance and spatial distribution, ordinary kriging method can work well in modeling them. The mean concentration of elements in the water followed the following pattern: Ca > Fe > Ba > Ni > As > Cr > Cu > Th > Co > pb. The mean concentration of elements (Co, Cr, Ni, Cu, pb and Th) demonstrate a similar pattern with a decreasing trend from the upstream to the downstream. This will strongly show a similar process and origin, while the mean concentration of Ba and As was increased at various sites from the upstream to the downstream.

### Conclusions

This study was carried out to determine the water quality of Tajan River and appropriate method of estimation and interpolation of its qualitative parameters based on the combination of linear regression and blind kriging. Twenty one water quality parameters were measured at ten stations on Tajan River, an inflow to the Caspian Sea in Northern Iran.

Tajan water quality is in the middle and relatively poor class based on IRWQI. The parameters of dissolved oxygen, barium, biochemical oxygen demand and fecal coliform exceeded the guidelines of Iranian water quality standards for protection of aquatic ecosystems. Combining blind kriging and linear regression methods can be useful to improve the ordinary kriging model by reducing the error of prediction. The ordinary kriging is a powerful method for estimating parameters that are highly correlated with distance and spatial structure. One of the limitations of the proposed method is that the analyst must perform different steps in different software environments, both statistical software and GIS, and it requires an additional cost of measuring the parameters used to create the deterministic mean function (regression). Therefore, this limitation should be considered in future studies. The results of this study can be useful in formulating water quality monitoring program of Tajan river water.

**Keywords:** geostatistics, ordinary kriging, Tajan river, universal kriging, water quality index.

## Health assessment of water quality of Madarsoo River (Golestan province) using multimetric biological index

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### Extended abstract

#### Introduction

There are several ways to monitor macroinvertebrate communities as a biological indicator of river health. One of these methods is a comprehensive method in Australia, the SIGNAL Index (average level of the number of invertebrate streams, SIGNAL) that assesses the degree of susceptibility to contamination for all major species of invertebrates in Australia. Based on the species at each station, the high sensitivity of inanimate invertebrates is used to calculate the water quality rating of streams or other water bodies. Also, the use of the EQR index, which is a multi-criteria indicator, 18 ecological factors from macroinvertebrate, evaluates the ecology of the river. The EQR is the latest multi-criteria indicator for water ecological assessment, first used in the Vietnam River in 2015. This study was conducted with the aim of identifying the macroinvertebrate and also in order to evaluate the efficiency of multi-criteria indicators for determining the biological health of Madarsoo river water, in Golestan forest using macroinvertebrate in large quantities and EQR index.

#### Materials and Methods

This research was carried out in 2018 from three seasons of spring, autumn and winter (no sampling in summer due to reduced Dubai and in some parts of the river without water) in the upper part of the river of Golestan forest area to the end of the strait in four stations. Sampling was performed using a sampler (30 × 30 cm).

The Biological SIGNAL Index was set to assess water health in Australia. The index measures water quality from 1 (pollution-resistant) to 10 (pollution-sensitive) and gives each family a score between 0 and 10 based on its susceptibility to pollution. In the evaluation method, using a macroinvertebrate, many parameters and taxon richness are combined with the index of species resistant.

The Multi-Indicator Index (MMIF) describes the status of an ecosystem by several basic indices. Each of these variables offers a different combination of ecosystem quality and is evaluated in one indicator. Composite indices were first used for fish communities and later for other index groups such as the macroinvertebrate. The Ecological Quality Ratio Index (EQR) is one of the most recent multivariate indicators in 2014, which evaluates the ecological integrity of a river based on 18 macroinvertebrate ecological parameters.

#### Discussion of results

River in the Golestan forest area were sampled, identified and counted. The macroinvertebrate of the Madarsoo River is given in Table 5. The most common of the unidentified organisms were Chironomidae (255, 32.9%) and after Caenidae (178, 22.97%) and Baetidae (118, 15.23%) of the order Ephemeroptera. The most diverse groups identified were Diptera (37.5%) and Ephemeroptera (18.75%), respectively. The larvae of aquatic insects accounted for the largest population of invertebrates. Macroinvertebrate were available in all seasons, with only Decapoda (Station 1) and Physidae (Station 2) being observed in the fall. The highest frequency was recorded at station 1 (35%) and 2 (25%) and the lowest frequency was recorded at Station 4 (19%). The study of

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macroinvertebrate abundance in four stations from Madarsoo River among the study seasons showed that in autumn (48%) the highest abundance and in winter (21%), the lowest abundance in this river.

This river has the largest number of low quality water pollution stations. The results of the SIGNAL index show that most stations are on less pollution class and only Station 4 are on class b in all seasons. The highest value of this index was observed in station 1 (1.5) in spring and the lowest in Station 4 (3.1) in winter. The SIGNAL 2 index also showed that only the Station 1 in the study seasons is higher than 4 and is in the fourth a. However the value of the index in other stations is less than 4 and according to the number of species, this station is in a quarter b. The lowest value of SIGNAL 2 (3.11) was observed at Station 3 in winter.

The results of the MMIF composite index show that the ecological situation and the level of pollution in the mother river in the spring are in better condition. In general, 3 qualitative class (good, medium and bad) of this index were observed in Madarsoo River in 2018. Stations 1 and 2 were on the good class in the spring, Stations 1 and 2 were in the fall, and stations 1 were in the middle class during the winter, and the other stations were on the bad class. Station 1 was on the good quality class and Station 4 was on the bad quality class EQR. The highest value of this index is 0.9 in Station 1 and the lowest value is 0.24 of Station 4.

### Conclusions

Higher average SIGNAL rating than Stations 1 and 2 compared to a lower score on Stations 3 and 4 indicates that more infected species such as Baetidae and Heptageniidae live in natural environments. This indicator suggests that susceptible species such as Trichoptera and Ephemeroptera can also live in areas exposed to relative organic pollution with suitable environmental conditions.

The EQR index describes Station 1 as a control station with good quality. Station 2 was also described as of good quality, with recent natural or human activity causing reversible changes at the station. Station 3 is of medium quality and that often human activities disrupt some of the ecological relationships of living societies. Station 4 is also on a poor quality floor, which needs to be rebuilt and planned to reduce the number of works immediately.

Nowadays, aquatic organisms are used as biological indices to assess the quality of ecological water. Therefore, we used multimetric indicators, including MMI, to assess the water quality of the Madarsoo River. Unfortunately, based on the indicators studied, some stations are in poor quality. In particular, downstream stations are affected by human activities and land use change. These results are important for local river managers studied, as well as other rivers in northern Iran that are under the same land use stress. Monitoring and evaluation tools for water resources management are usually more effective if they are based on a clear understanding of the mechanisms that lead to the presence or absence of species in the environment. The results showed that the SIGNAL and EQR indicators are suitable for assessing river health by macroinvertebrate.

**Keywords:** biological index, biological quality of water, macroinvertebrate, Madarsoo River.

## Modeling of flow Hydrodynamics and Biological Oxygen Demand changes in the wetlands (Case study: The GoleNilofar wetland, Babol, Iran)

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### Extended abstract

#### Introduction

Among surface water resources, wetlands have special importance in providing habitat for various plant and animal species due to their ecological roles. Wetlands are swampy areas, reservoirs, and natural and man-made ponds that have static or flowing water, fresh or saline, permanent or temporary. One of the most important but little known traits of wetlands is to improve surface water quality. These systems can provide effective treatment for a variety of contaminants in the water, hence they are known as "natural water purifiers". Removal of pollutants occurs by the effect of simultaneous operation of physical, chemical, and biological processes including deposition, filtration, chemical reduction, adsorption, biodegradation, photo-oxidation, consumption by animals and plants, etc. The mechanisms and interdependencies between the ecological components of the wetland are complex and many of them are not yet fully understood.

With the development of technology and the use of computers in engineering processes, the use of computer models to simulate ecological processes in natural ecosystems has become very common during the last years. Therefore, making an appropriate hydrodynamic model of the water body with the ability to simulate the affecting processes for the fate and transmission of the pollutant, has become a technical necessity.

So far, several field studies and computer simulations have been reported to evaluate the efficiency of the wetlands to improve water quality under the predicted load of pollution entering the wetlands. The experience of using mathematical models for the simulation of the wetlands has shown the high ability of these models for the simulation of the complex ecological processes. So, the computer models have seriously been considered as a modern tool for the management of wetlands and improving its purification efficiency.

#### Materials and Methods

In the current study, the experiences of Babol city in the province of Mazandaran for the planning of a city wetland i.e. GoleNilofar wetland, to the common space is reported. The hydraulic retention times in wetland different basins are about 20 to 60 days. The inflow to the wetland is not changing along the seasons and was measured about 0.153 m<sup>3</sup>/s in spring, 0.157 m<sup>3</sup>/s in summer, 0.273 in fall and 0.217 m<sup>3</sup>/s in winter

In this study, the computer model of the GoleNilofar wetland is developed using Hydrodynamic and ECOLab modules of the MIKE3 software. The FM hydrodynamic model is a basic numerical model for the flow simulation in MIKE3 that can be used in all water bodies i.e. the wetlands, rivers, bays, coastal waters, and open oceans. This model can simulate the flow unsteady three-dimensional features in the conditions of density changes in the environment. The model can simulate the impacts of external forces including meteorological and tidal parameters. The EcoLab module of MIKE software was developed as a modeling tool to investigate the effects of natural aeration, sunlight photooxidation, and sedimentation together with the plants and bacterial uptakes on the fate of organic matter and purification capability of the different water bodies. In the simulations, only BOD (Biochemical Oxygen Demand) time variations and spatial changes in the wetland were investigated. The amount of oxygen needed by microorganisms for the oxidation of degradable materials within 5 days is called BOD<sub>5</sub> i.e. 5-day biological oxygen demand. Biological oxygen demand is one of the most important indicators of water pollution. Water contamination is caused by external material in a suspended or dissolved form that changes the physical, chemical, and biological properties of water.

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## Discussion of results

The BOD of the inflow was measured by sampling the incoming current in different seasons along 1398 (2019-2020). The BOD together with the discharge flow rate, temperature, and density of the water are modeling inputs that are required for the simulation. Here in this paper, the results of the wetland ecological simulations have been reported for the season of the spring. This season is selected as it is the beginning of a growing season in the wetland. To better investigate the distribution of pollutants and the changes in the flow properties, the water body of the wetland is assumed to be stationary and the concentration of BOD is considered equal to zero at the beginning of the simulation. So, the inflow to the wetland (to the pond 1) was measured  $0.153 \text{ m}^3/\text{s}$  and the BOD of incoming water was measured  $5.5 \text{ mg/l}$ , both of which did not change significantly during the spring. The time interval of 3 hours and the number of steps of 735, equivalent to one whole season is introduced to the model. Finally, the simulation results at the end of spring were compared with the observed values from the field sampling at the beginning of summer.

As a result of hydrodynamic modeling when the wind speed is at its maximum during the season, i.e.  $9 \text{ m/s}$ , the flow velocity in the wetland is also at its maximum. For wind speeds of  $9 \text{ m/s}$ , the velocity of the surface flow was above  $0.37 \text{ m/s}$ , which due to the closed boundaries of the environment, lead to deep current and material conduction to water depth. Ecological modeling exhibited that due to the chemical and biological processes, as well as the long retention time of the pollution in the wetland, distancing from the entrance, the BOD decreases clearly. According to the discharge flow rate and volume of each pond, the retention time in the first pond is about 18 days, in the second pond 24 days, and the third pond 73 days. The results also showed that the amount of BOD entering the wetland ( $5.5 \text{ mg/l}$ ) at the end of spring and early summer reaches  $4.7 \text{ mg/l}$  at output 1 and about  $3 \text{ mg/l}$  at output 2. The field measurements of BOD at the beginning of summer in both outlets showed the values of 4 and  $3.4 \text{ mg/l}$ , respectively. Comparison of the modeling results with our field observation at the end of this season exhibited that the model can predict the BOD concentration with 80% accuracy without adjusting the coefficients and only using the values reported for similar conditions in previous studies.

## Conclusions

In this work, an ecological model has developed using the ECOLab module of MIKE3 for the Gole-Niloufar wetland which is an urban wetland in the city of Babol, north of Iran. The capability of the wetland to improve the quality of incoming water has been discussed. This waterbody is a valuable natural resource in the region in terms of entertainment and recreation and has been used to supply water to rice farms downstream. In the developed model, the wetland is simulated during the spring for 93 days with 735 of 3-hour time steps in which the actual data of the inflow and BOD have been utilized. The BOD parameter was selected as an indicator of contamination to the organic matters and the process of transfer, diffusion, and decomposition were investigated by hydrodynamics modeling of the flow and the simulation of the BOD degradation in the wetland. The calculated values were compared with the field measurements at the end of the season and the accuracy of the model was investigated. A comparative study of the results with the field data exhibited that the model can predict the degradation of BOD concentration in the ponds. The results of this study showed that due to the high retention time, low flow rate, and the natural rehabilitation and purification, this wetland can reduce pollution to a desirable level. It has also been observed that the water quality of the wetland depends on the physical, chemical, and biological processes of wetland beside the properties of the incoming water. So, improving the wetland performances from this perspective can ensure the safe use of water downstream.

**Keywords:** biological oxygen demand, hydrodynamic of flow, natural treatment, wetland.

## Investigating the influence of Architectural Features on thermal behavior of dominant residential structure patterns in Tabriz housing

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### Extended abstract

#### Introduction

Although the industrial sector has the largest amount of energy consumption, the share of residential sector is very high, yet. According to the global statistics released by the US Department of Energy in March 2010, energy is used in several segments of residential buildings. Amongst all segments, heating systems use the highest level of energy. Next levels of energy consumption relates to lightings and cooling systems, respectively. Since a large portion of energy is exploited by construction sector, the study of typology in the field of housing would be beneficial for professionals in terms of performance.

The aim of this study is to provide designers, constructors, and consumers with useful measures for high performance residential construction in the city of Tabriz. Consideration of such measures together with correct design strategies at the early stages of design and construction leads to optimization of energy consumption in residential sector. Thus, residential constructions would be sustainable in cold climate of the region with optimal energy consumption.

The first part of this paper, serves as a literature review, which studies research background and similar works in this field. In addition, based on the survey conducted in this part, the importance of the present work is defined. The second part of the paper describes the research methodology used in this paper. This part includes: climate description of the region, simulation method and scenarios related to thermal comfort in the city of Tabriz. In the third part, simulation results are analyzed and validated. This paper concludes by comparison of thermal behavior of three dominant residential structure patterns and the most sustainable structure pattern that is capable of achieving the optimal energy consumption in Tabriz environment. Moreover, the influences of several architectural design parameters on energy consumption in Tabriz housing are investigated.

A large number of research, imply parameters that are determined at the early stages of design have great effect on the energy consumption of the building. Research shows that 57% of energy-saving technical measures should be considered at the design stage and shows that residential structure design should be revised in a way that location of spaces in the plan follows the pattern of space occupation with respect of the solar cycle. They recommend the use of suitable shutters and glass and also suggest replacement of renewable energy.

This research is aligned with studies conducted by Hashemi et al. for the city of Ardabil that has similar climate condition to Tabriz. However, they have measured the amount of energy required for both heating and cooling with respect to the internal aspects of structures and also studied the effect of zoning and location of spaces in the plan, whereas the present study considers different parameters regarded to external aspects of residential structures that affect the thermal behavior of residential structures. Moreover, this research studies the thermal behavior of dominant residential structure patterns in the city of Tabriz to define significant features of architectural design to be considered under cold climate conditions as well as during hot season.

#### Materials and Methods

In this research thermal behavior of three dominant residential structure patterns, including traditional courtyard, row house, and high-rise building is studied to determine the most sustainable structure pattern that is capable of achieving the optimal energy consumption in Tabriz environment. For this purpose, the thermal behavior of each type of structure patterns is carefully studied from different aspects. With this regard, the influences of several architectural design parameters on energy consumption are investigated to provide designers, constructors, and consumers with useful measures for residential construction in the city of Tabriz. In this research, form of the structure and age of the building are selected as two independent parameters according to national thermal

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standards. In addition, four variable parameters namely orientation, construction materials, type of overlay, and insulation are also measured. Effects of these parameters on energy consumption are studied for all three types of structure patterns considered in this research. Thermal behavior of each type of structure patterns is simulated using “Ecotect” software. The simulation results are then analyzed using “EnergyPlus” software. In addition, for validation of the results obtained through software simulation, a number of consumers’ bills related to each structure pattern are collected as field impressions and comparison of energy consumption is conducted.

In order to determine the importance of each architectural feature for each type of structure, the criteria are weighted using AHP (Analytic Hierarchy Process) method. Hence, variable parameters together with independent parameters are organized in a matrix, and then multiple criteria are weighted using AHP method. Calculation of multiple weighted criteria results in precedence of parameters. Thus, the importance of each parameter in each pattern is determined.

### Discussion of results

First, all three models are simulated and the amount of annual energy consumption for heating and cooling for each month is measured and the results are presented as bar charts accordingly. The results show that the highest level of energy required for heating is during November to April, which is due to the cold climate of Tabriz.

This amount exists on average and with a significant difference between a high-rise building with a row house and a courtyard house. Thus, considering the amount of energy required for heating regarded to square meters of the building, with a high difference, the high-rise pattern with lowest amount achieved the most optimal level of energy consumption. Among the other two patterns, the amount of energy consumption for heating in a courtyard house is slightly higher than in a row house. According to the results, the percentage of total amount of energy required for heating for each pattern is 43.2% for B.M.1, 42.8% for B.M.2, and 14% for B.M.3, respectively.

On the other hand, the results show that the highest level of energy required for cooling is during January to September, which is due to the short summer season in Tabriz.

Based on the obtained results, the traditional courtyard pattern has the advantage of proper climate design in that slight amount of energy is required for cooling. On the other hand, the high-rise building requires the highest amount of energy for cooling. Yet, this pattern provides the best heating performance due to proper insulation and also for the maximum use of sunlight. According to the results, the percentage of total amount of energy required for heating for each pattern is 21.8% for B.M.1, 34.7% for B.M.2, and 43.5% for B.M.3, respectively.

Based on calculations of the weighted parameters, significant architectural features are insulation (0.41), type of opening (0.32), construction materials (0.23), and orientation (0.04), respectively. In fact, consideration of these measures at the early stages of designing residential structures leads to optimal energy consumption in Tabriz environment.

### Conclusions

In this paper, thermal behavior of three dominant residential structure patterns in Tabriz housing is studied to find out how different architectural features affect energy performance of residential structures. Overall, the outcomes of this study can be summarized as below:

1. The effect of independent parameters on the amount of energy required for heating and cooling is presented.
2. Numerical figures indicate that the amount of energy required for heating residential structures under cold weather conditions are three times more than the amount needed for cooling them during hot season.
3. Based on this study, the high-rise building pattern provides the best heating performance due to appropriate insulation and also for the maximum use of sunlight; however, this type of structure has low performance in term of energy required for cooling, which is due to large openings in front design of this type of structure.
4. According to the analytical data, the row house pattern (the urban block model of 60% density) fails to compete with other residential structure patterns in terms of energy performance.
5. Generally, due to the cool weather condition in Tabriz during May to October, there is no need for any cooling or heating equipment for residential structures, and the weather conditions comply with the thermal comfort situation.
6. Simulations confirm the importance of selecting appropriate form of the structure as well as correct direction of the structure considering the maximum absorption of direct sunlight. Appropriate selection of these parameters improves the energy performance in terms of heating residential structures under cold weather condition in Tabriz.
7. Calculations performed using AHP method, determines that architectural features including insulation, type of opening, construction materials, and orientation have great impact on thermal behavior of residential structures in Tabriz housing. In fact, consideration of these influential features at the early stages of designing residential structures leads to optimal energy consumption in Tabriz environment.

**Keywords:** climate design, energy consumption, optimization, Tabriz housing, thermal behavior.

## The fusing of satellite images and using particle swarm optimization algorithm to improving evaluation of water body, focusing on monitoring and identifying flood

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### Extended abstract

#### Introduction

Every year crises and natural disasters affect many countries, and it causes economic and human losses. Iran is one of the countries that are facing a lot of events of natural disasters. In research, it has attempted to present an appropriate and efficient solution in this field. In this regard, a method for identifying water bodies can be advantageous in monitoring water bodies and identifying and monitoring and estimating flood damage. At the beginning of the research, appropriate images were placed and collected. In the next step, higher resolution images have been fused to reducing the mixed pixels and increasing the accuracy of the results and analysis in the proposed method. Then, spectral reflectance in the water-sensitive bands was used. Compared with the standard reflectance value identified for the water in the same bands, probable water existence images were provided. According to the studies and appropriate capabilities, the particle swarm optimization algorithm was founded on this research's purpose method. Finally, optimizing the introduced objective function was tried to consider the nature of water and flood behavior, and the results were evaluated visually and statistically using two classification methods.

#### Materials and Methods

The proposed method of this research is done in two primary and general stages: in the first stage, a water probability map is extracted from the images, and then in the second stage, the proposed water probability map is optimized with a particle swarm algorithm.

The functions used in this study are as follows: Relationship 1 is The function of calculating the probability map of water; Relationship 2 is the objective function (Jia et al., 2018); Relationships 3 and 4 (Karamouz et al., 2014) are a function of the particle swarm algorithm (Samadzadegan & Alizadeh, 2011; Bahrami et al., 2019).

$$P_w = \cos(\vec{W}, \vec{O}) * dist(\vec{W} * \vec{O}) \quad (1)$$

$$T = k_1 \sum_{k=1}^{rows*cols} P_{w,k} + k_2 \sum_{k=1}^{rows*cols} P_{nw,k} - k_3 \frac{\bar{D}_{nearest}}{\sqrt{rows^2 + cols^2}} \quad (2)$$

$$v_i = wv_i + c_1 \vec{\varphi}_{1i} (\vec{p}_i - \vec{x}_i) + c_2 \vec{\varphi}_{2i} (\vec{p}_g - \vec{x}_i) \quad (3)$$

$$\vec{x}_i = \vec{x}_i + \vec{v}_i \quad (4)$$

## Discussion of results

Part of the Caspian Sea has been selected as a suitable study area due to pure water bodies. Images of the Landsat 8 satellite, the OLI sensor, have been used as the data source to prevent various sensors' impact. All images selected are cloudless to reduce cloud impact. To time minimizing process, a clipping of images has been considered. Some of the images were to validating this purpose method. The resolution of Landsat images (30 m) is vast for identifying small pieces with mixed pixels. For the increasing spatial resolution of images, the IHS image fusion algorithm has been used with the panchromatic image.

Due to water's spectral behavior in different bands, NIR, SWIR, and Green bands were recognized and used. March 2019 has been considered due to the floods around the Caspian Sea. The study area was selected as part of the Caspian Sea border, around Kiashahr near Lahijan. In the first step, to improve the final results' accuracy, the chosen bands were combined with a panchromatic band that has twice the resolution (15 m) of the above bands.

In the next step, small areas in the deeper part of the sea that do not have cloud cover were used as the standard reflectance of water and calculate the classification error. The band's vector angle values and the water reflectance standard value (such as the SAM method), and the distance their values were used to create the map. Probability water in each pixel, its reflectance proximity to the standard reflectance of water in the same band, will be between 0 and 1.

After creating a probabilistic map of water's existence, this map enters the optimization algorithm as a relatively simple classification. The goal of implementing an optimization algorithm that is detecting and extracting the water range from images and creating a map of water's probability can be an excellent initial solution for better implementing the algorithm. In the optimization algorithm, before implementing such algorithms, the objective function should be defined and used to optimize the problem.

When its value is more valuable in this problem, that is a larger value. In this research, a means of maximized value is more probability of water. Function and particle swarm algorithm coefficients have been determined from the beginning of the algorithm implementation.  $c_1$ ,  $c_2$ ,  $\phi_1$ ,  $\phi_2$ , and  $w$ , in the PSO algorithm structure,  $k_1$ ,  $k_2$ , and  $k_3$  in the objective function are coefficients whose values were determined.

Suitable values for  $c_1$ ,  $c_2$  in the range [2.2, 1.8] so that the sum is equal to 4; These two coefficients determine the effect of the best individual response and collective response in the particle swarm algorithm; in other words, it is possible to choose the tendency to local or global optimizations. Therefore, these two coefficients were selected in the mentioned interval to have an optimal and balanced state of the algorithm implementation process and responses.

The coefficient  $W$ , which controls the convergence process of the algorithm, is equal to 1. The reduction coefficient  $W$  (convergence coefficient of the algorithm) was considered in the next iterations similar to  $0.05 \phi_1$ ,  $\phi_2$  being random numbers determined in each iteration of the algorithm to move towards the answers in new and unexplored spaces.  $k_1$ ,  $k_2$ , and  $k_3$  were considered equal to 0.9, 0.5, 1, respectively, according to the climatic conditions of the study area. As it is clear from the study area's position, due to the placement of water and land next to each other, consequently increasing the probability of water pixels and reducing the likelihood of lack of water and reducing the distance with pixels water, were considered.

At each stage of implementation, the pixels' status was compared with the objective function's best solution, if it is better than the best solution to replace. In addition to each pixel, it will have saved the objective function calculated for the whole range. If the response was better than the optimal state of the global solution, it was replaced. In this way, the answers have been compared with the most optimal solution due to the algorithm's defining conditions. Finally, after 500 repetitions, the algorithm ends.

By studying and checking the optimization algorithms, the particle swarm algorithm as a collective intelligence algorithm takes effects of the neighborhood (Bahrami et al., 2019) and according to the water behavior and creating floods, will be advantageous. This algorithm was selected using an objective function that would cover the essential issues and consider the water probability in the points and the neighbors' impact. In research to improve the algorithm, a relatively right initial solution was created by the probabilistic maps of water present in the pixels and the spectral behavior of water and spectral reflection in the used bands.

## Conclusion

Finally, the proposed algorithm's performance was visually and statistically compared with several other classification methods such as SVM and k-means. The Overall Accuracy and Kappa Coefficient values were calculated and compared for statistical comparison. The OA value of 98.93% for the proposed algorithm, 98.39% for SVM and 96.73% for k-means, and KC 95.6%, 91.2%, and 67.8% for the proposed research algorithm SVM and k-means. As a result, the proposed algorithm was found to be useful and appropriate in this problem. Figure 2 is a statistical comparison chart of the proposed method and methods of SVM and k-means.

**Keywords:** data fusion, floods, optimization, particle swarm algorithm, time, water body.

## The performance of modified pumice by TEPA in adsorption of CO<sub>2</sub> in process industries

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### Expanded Abstract

#### Introduction

The overuse of fossil fuels to supply the fast-growing population of the earth with their needed energy, as well as advanced technologies and industrial development have led to the emission of great amount of greenhouse gases. From among the greenhouse gases, CO<sub>2</sub> is of particular importance and accounts for around 60% of the effects of global warming. The best long-term solution to reduce the amount of released CO<sub>2</sub> is through its adsorption and sedimentation. As the adsorption stage in carbon capture and storage (CCS) technology is the most expensive phase (70-90% of the total costs), conducting research into solid adsorbents and increasing their CO<sub>2</sub> adsorption capacity seems reasonable. As a result, adsorbents made of natural and eco-friendly materials, which are economical and do not necessitate the use of complicated synthesis processes, are of considerable importance. In order to fulfill such a goal, this study, for the first time, examined the CO<sub>2</sub> adsorption capacity of raw (natural) pumice as a green adsorbent. A considerable body of previous research has focused different applications of pumice since 1995. The majority of the studies were related to the removal of pollutants in water and wastewater treatment. After an exhaustive review of the literature, it seems that the available body of research is void of any findings regarding the use of pumice modified with Tetraethylenepentamine (TEPA) as a CO<sub>2</sub> adsorbent. Having large contact surface, high porosity (90% on average), and -OH group, this igneous rock seems a suitable choice for the adsorption process. The performance of the adsorbent could be improved if functional groups with high affinity to adsorb CO<sub>2</sub> is added to it. Highly porous solids and amine groups can make a very suitable compound to achieve high adsorption rates. According to the recent studies on the selective adsorption of CO<sub>2</sub> by amine compounds, TEPA enjoyed the highest adsorption, and therefore was selected in this study as the added substance to pumice.

#### Materials and Methods

In this study, a new method was used to modify the pumice taken from Maragheh mine. In this method, 0.01 moles of 2-(3,4-epoxycyclohexyl) ethyltrimethoxysilane (2.88 grams) to increase adhesion, and 0.01 moles of tetraethylenepentamine (1.89 grams) were mixed in a 50cc beaker containing 10 milliliters of isopropylamine with oxirene ring. The product was used as the modifying agent and was added to powdered pumice at the mass percentage of 6%. This involved adding 10 milliliters of the solution of water: ethanol (1:10 volume fraction) to 10 gr of the powder and the modifying agent (6%) was added to the beaker while being stirred. The content of the beaker was mixed with 0.01% ammonia solution for 1 hour at 60°C. The sediment was poured on filter paper, rinsed three times with 60% ethanol, and left in the oven for four hours at 60°C to completely dry.

First, the CO<sub>2</sub> adsorption capacity of raw pumice and then that of pumice modified with 6% TEPA were measured using the BELSORP-max instrument. Then, the Ideal Adsorption Solution Theory equations were calculated. The analytical equation of spreading pressure is presented based on Toth isotherm:

$$\frac{\pi_i A}{RT} = \frac{y_i P_{tot} K_{Ti} q_{s,i}}{x_i} {}_2F_1\left(\frac{1}{t_i}; \frac{1}{t_i}; \left(1 + \frac{1}{t_i}\right); -\left(\frac{y_i P_{tot} K_{Ti} q_{s,i}}{x_i}\right)^{t_i}\right) \quad (1)$$

The selectivity of CO<sub>2</sub> to N<sub>2</sub> is calculated using the following formula:

$$\text{Selectivity} = \left( \frac{x_{\text{CO}_2}/x_{\text{N}_2}}{y_{\text{CO}_2}/y_{\text{N}_2}} \right) \quad (2)$$

The adsorbent performance indicator (API) is calculated using the material balance equation for the three parameters of adsorption capacity, selectivity, and adsorption enthalpy.

$$\text{API} = \frac{(s_{1/2}-1)^A \times W C_1^B}{|Q_{ST,1}|^C} \quad (3)$$

According to the following equations, the shares of physical and chemical adsorption on the total amount of adsorption (of the adsorbate on the selected adsorbent) can be calculated.

$$q = \left[ \frac{q_s K_T P}{(1 + (K_T P)^\tau)^{1/\tau}} \right]_{\text{Chem}} + \left[ \frac{q_s K_T P}{(1 + (K_T P)^\tau)^{1/\tau}} \right]_{\text{Phys}} \quad (4)$$

### Discussion of results

The results of the XRF test revealed SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> to be the main constituents of pumice. In the XRD results of pumice (from Maragheh) crystal phase was seen when  $2\theta = 23, 25.28, 5, 31, 32.5, 33, 41.5$ . According to the FT-IR results, in this sample features of SiO<sub>4</sub> group was observed at 1033 cm<sup>-1</sup>, 1037 cm<sup>-1</sup>, 1048 cm<sup>-1</sup>, 461 cm<sup>-1</sup>, and 780 cm<sup>-1</sup> wavelengths. The morphology of the sample pumice examined using *scanning electron microscope (SEM)* demonstrated that in the sample, the amorphous structure of lamella is split into uneven phases and bonds which shows evenly spread pores are extruded in nature. According to the results, the CO<sub>2</sub> adsorption capacity of pumice from Maragheh was around 0.230 mmol/g. This figure for the modified pumice was around 0.510 mmol/g, which is twice as much as that of raw (natural) pumice. Increasing the temperature affected the CO<sub>2</sub> adsorption capacity negatively and at 298K, 328K, and 348K, the adsorption capacity was calculated to be around 0.510 mmol/g, 0.402 mmol/g, and 0.357 mmol/g, respectively. The values of reduced spreading pressure were measured as molar fractions of the adsorbed CO<sub>2</sub> on 6% TEPA modified pumice at 298K and different CO<sub>2</sub> concentrations of 5%, 15%, 25%, and 35% by volume, and were 0.2, 0.4, 0.5, and 0.6, respectively. Consequently, the adsorbent's selectivity of CO<sub>2</sub> molecules compared to N<sub>2</sub> is possible to estimate. The results reflecting the CO<sub>2</sub> working capacity after the alteration of the concentration of CO<sub>2</sub> revealed that the higher the concentration of CO<sub>2</sub> is the better the modified pumice adsorbent performs. The selectivity of CO<sub>2</sub> on modified pumice showed that if the CO<sub>2</sub> concentration (partial pressure) rises, the rate of adsorption decreases. This point is justified because molecules of CO<sub>2</sub> have high affinity for the sites with more adsorption energy in comparison with N<sub>2</sub> molecules. Moreover, when the pressure increases and high-energy sites get full, CO<sub>2</sub> and N<sub>2</sub> molecules compete to sit on the sites with lower energy (which are of less value in terms of selectivity). When the volume percentages of CO<sub>2</sub> were 35 and 25 (which is the common case in cement industry), the rates of selectivity were 2.79 and 3, respectively. When the concentration of CO<sub>2</sub> was 15% by volume (the common case at coal power plants), the amount of selectivity was equal to 3.76. This amount with CO<sub>2</sub> at 5% by volume (common in combined cycle and gas turbine power plants) was 4.75.

The calculation of the adsorbent performance indicator (API) leads to the fact that the performance of the adsorbent is better at lower rates of CO<sub>2</sub> concentration. The change in the heat stemming from adsorption (Q<sub>is</sub>) during the process at different percentages of CO<sub>2</sub> proved that adsorption actually took place and that the process was an exothermic one. The calculations of thermodynamical parameters of the adsorption of CO<sub>2</sub> on 6% TEPA modified pumice, at 298K, revealed that -5.2 KJ/mol and -0.008 KJ/mol are needed to, respectively, change the enthalpy (ΔH°) and the entropy (ΔS°) of the reaction between the adsorbate and adsorbent. The subtraction of these two figures gives us the changes in Gibbs free energy (ΔG°), which equals -5.192 (K). Following the experimental findings, the negative value of (ΔH°) shows that the process of adsorbing CO<sub>2</sub> is exothermic. In addition, this value shows the type of the adsorption process. The value below 20 means that physical adsorption is at work. The negative value of (ΔG°) at low temperatures shows that the adsorption process was spontaneous. The investigation of CO<sub>2</sub> concentration effect on the adsorption capacity and adsorption performance indicator (API) of modified pumice in process units revealed that the lower the concentration of CO<sub>2</sub> had the better performance of the adsorbent. In addition, the thermodynamic parameters proved that the process of CO<sub>2</sub> adsorption on modified pumice was physisorption as well as exothermic and spontaneous. Despite the lower CO<sub>2</sub> adsorption capacity for pumice in comparison with other synthesized adsorbents, it has the lower cost of production when compared to other adsorbents, along with its accessibility due to the large number of mines in the country which illustrates its commercial use.

### Conclusion

In this study, the experimental results of CO<sub>2</sub> adsorption capacity of raw pumice and amine-modified pumice were compared. The natural (raw) pumice demonstrated the CO<sub>2</sub> adsorption capacity of 0.230 mmol/g. There was a considerable increase in the amount of CO<sub>2</sub> adsorption capacity when pumice was modified using 6% TEPA content (0.510 mmol/g), which showed the adsorbents better performance next to the amine compound.

This point has already been proved in several other studies on adsorbents. Upon alterations of the temperature, the adsorption capacity at 298K, 328K, and 348K was higher than that of raw pumice at 298K. Additionally, the highest rate of CO<sub>2</sub> adsorption in the modified sample was observed at 298K, which signals that a lower temperature is more favorable for 6% TEPA-modified pumice. When the volume percentages of CO<sub>2</sub> were 35 vol% and 25 vol% (which is the common case in cement industry), the selectivity of CO<sub>2</sub> over N<sub>2</sub> were 2.79 and 3, respectively. When the concentration of CO<sub>2</sub> was 15 vol% (the common case at coal power plants), the amount of selectivity was equal to 3.76. This amount with CO<sub>2</sub> at 5 vol% (common in combined cycle and gas turbine power plants) was 4.75.

**Keywords:** adsorbent performance indicator, CO<sub>2</sub> adsorption capacity, pumice, selectivity.