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Temporal and spatial study of water use productivity of strategic crops in regional scale (Case study: Hamedan province)

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Abstract

Water use productivity is one of the most important factors in scientific agriculture. It is equal to 0. 7 kg of production per cubic meter of irrigation water (Kg/m^3) in Iran which is very low in comparison with advanced countries (1 to 2 Kg/m^3). Current research studies temporal and spatial changes of water use productivity in Hamedan province in Iran using Geographic Information System (GIS), as to find evapotranspiration values for wheat and to transform it to raster level using Inverse Weight Distance Interpolation (IDW) in ArcGIS9.2 software. As location and time dimensions are studied simultaneously, combination of both leads to more effective analysis.

Evapotranspiration is the denominator of water use productivity and the nominator is products' performance which the values are obtained using statistics of Iran Agriculture Ministry and Hamedan province Agricultural Organization in particular and location extension map for wheat productivity is obtained from overlay of 2 raster of evapotranspiration layer and the performance layer.

Keywords

Geographic Information System (GIS), water use productivity, evapotranspiration, products performance.

1. Introduction

The world population has increased to over 6 billion from 2.5 billion during the recent 50 years. The population of Iran has also gone through the same trend and increased to about 65 million in the beginning of 2001 decade from 6 million in the past 45 years. It is anticipated that the population of Iran increases to about 100 million in 2021 despite implementation of all the population planning programs (Ehsani, Khaledi, 2003). Considering the increase of population and the amount of water use under the present circumstances, there is need to over 266 billion m^3 of water in 2021 and the existing water resources are unable to create such a water volume (Jahani, 2000). Hence in order to respond to this increase of demand and secure the food demand of the society, comprehensive studies should be conducted from now to complete agricultural planning in order to make the best of economy of different climate regimes of Iran and to increase water

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use productivity from 0.7 to 1.8 - 2 Kg/m^3 (Sadeghzadeh, Keshavarz, 2000). The main concept of water productivity is to understand how to be able to use the different available agricultural water production systems in one field or region (considering the shortage of water) in a more effective way (Kjine *et al*., 2003). With a more precise definition, it could be named the physical mass or assessed economic value of the product against gross entering current, net entering current, evacuated water, water evacuation process and or accessible water (Sakthivadivel, Molden, 1999).

Studies and researches regarding water use productivity for different agricultural products have been conducted in the regional scale among which the studies conducted by Heinemann *et al*., (2001) in the Territory of Tibaji River could be named using a combination of geographical information system and plant models. They showed that the cloning models of the agricultural product that were combined with the agricultural information system could be considered as a suitable means in order to estimate the irrigation need of water use productivity for the territories of small rivers or the big territories. Amor (2001) did the cloning of three products of rice, corn and peanuts fewer than two conditions of the existing agricultural lands and potentials in the Territory of Lavag River in the Philippines for the productivity study of water within time and location dimensions. The results showed that the time and location analysis of water use productivity could present considerable information regarding the opportunities to store water and the strategies of irrigated agriculture. Theib Oweis and Ahmed Hachum (2004) also conducted research regarding the improvement of water use productivity in the dry farming regions of west Asia and North Africa Also diagnostic analysis of time and location variants in water system productivity of rice and wheat was conducted in Panjab, Pakistan at the farm scale by M D Ahmad *et al.,* (2004). The results showed that the difference in water use, date of cultivation, use of fertilizer, soil quality. The social-economic conditions lead to change of location, and the amount and time of precipitation is also an important factor in time changes. In other conducted studies in Sirsa, India by Ranvir Singh, the combination of eco-hydrologic model of soil-water, atmosphere, plant in the scale of farm through field information, remote assessment, and geographical information system show increase of credit of the cloning capability of water use productivity from the farm to region scale.

In order to determine the water use productivity, estimation of the products performance is required for which different methods exist and through which one can specify the amount of product performance for different regions. One of the most suitable methods is to use statistics and information of the Iran Ministry of Agricultural which is published in regional scale and on annual basis.

The aim of conducting this study is to review the changes of water use productivity in time and location scales simultaneously. In order to analyse the time changes of water use productivity, the standardized precipitation index (SPI) has been used and the difference of location and time changes of water use productivity throughout the region will be studied by development and combination of Geographical Information System (GIS) and reversed median finding of weight method.

2. Materials and Methods

Hamedan province is located in the geographical indices between 34 to 35 degrees and 46 minutes of northern latitude and between 47 degree and 48 minutes to 49 degree and 28 minutes east longitude. The area of the region of 19493 Km^2 is equal to 1.2% of the total area of the country. Hamedan province has semi-dry and cold climate and the average of annual precipitation is about 330 mm and the average annual temperature is 12 degree centigrade (^{0}C). From climate point of view, the region under study is part of semi-dry and cold regions according to Celsianov classifications (Zare Abyaneh *et al*., 2005). In order to assess the conditions related to drought, wet year and normal, standardized precipitation index (SPI) is used.

The Standardized Precipitation Index (SPI) is a way of measuring drought. The SPI is a probability index that considers only precipitation.

The Standardized Precipitation Index (SPI) is a probability index that considers only precipitation. The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive.

The Standard Precipitation Index (SPI) was designed to enhance the detection of onset and monitoring of drought. The SPI is based solely on the probability of precipitation for a given time period. A key feature of the SPI is the flexibility to measure drought at different time scales.

Because droughts vary greatly in duration, it is important to detect and monitor them at a variety of time scales. Short-term droughts are measured by meteorological instruments and are defined according to specific regional climatology. Agriculturally important droughts result in deficits in soil moisture and three- to six-month droughts can have a great impact.

Table 1. The classification values for SPI values

SPI Value	Drought Category
2. 00 and above	Extremely wet
1. 50 to 1. 99	Very wet
1. 00 to 1. 49	Moderately wet
-0. 99 to 0. 99	Near normal
-1. 00 to -1. 49	Moderately dry
-1. 50 to -1. 99	Severely dry
-2. 00 and less	Extremely dry

Values of SPI are derived by comparing the total cumulative precipitation for a particular station or region over a specific time

interval (for example: the last month, the last 3 months, the last 6 months) with the average cumulative precipitation for that same time interval over the entire length of the record. The severity of a drought can be compared to the average condition for a particular station or region. The range of values are from 2.00 and above (extremely wet) to -2.00 and less (extremely dry) with near normal conditions ranging from 0.99 to - 0.99.

A drought event is defined when the SPI is continuously negative and reaches a value of -1.0 or less, and continues until the SPI becomes positive. Drought duration is defined by the interval between the beginning and end of that period. The magnitude of the drought event is measured by the sum of the SPI values for the months of the drought.

To do this research, precipitation data of 13 stations held by meteorology organization and regional water authority of Hamedan province was used in a joint time period of 29 years (1973-2002). In order to observe the principles of median finding, in addition to regional stations, 7 stations of assessing rain neighbouring the region under study were used. In the beginning we should have made sure about the homogeneity of data. Upon determining the joint time period (29 years), the correlation method among the stations was used to restore the statistical shortcomings (in a limited way) using SPSS software and the statistics of incomplete stations was completed according to the statistics of the station holding highest correlation index (Yazdani *et al*., 2005).Standardized precipitation index was prepared by a program and was calculated in Excel for a time scale of 12 months and the obtained results were studied in order to determine the relevant years as far as the three conditions of drought, humid and normal were concerned.

The maps related to the territory of the region were prepared and ArcGIS9.2 software was used for the turning operation the indexes system. The selected meteorological stations in and neighbouring the borders of the territory were set and all the required parameters of the method using the presented information were prepared by Food and Agriculture Organization (FAO) in addition to the conducted reports and researches within the region. Using the indexes of the selected meteorological stations and entering them into ArcGIS9.2 software, the spotted layer related to the meteorological stations was produced. Then using two NETWAT and OPTIWAT softwares, evapotranspiration of wheat for the meteorological stations was gained and was entered into description tables related to the spotted layer of stations.

At this stage, the vector spotted layer related to evapotranspiration of the products was produced, but since the information about the amount of evapotranspiration was needed in all parts of the province, the amount of evapotranspiration was calculated at the spots lacking statistics and this method was called interpolation and the method of internal distance reversed (IDW) was used. Using spatial analyst performer and then interpolation performer and using IDW option of evapotranspiration spotted layer of products turned to raster layer and the place extension map of evapotranspiration was achieved. (Fig. 3)

In order to determine the wheat water use productivity, in addition to evapotranspira tion that is the denominator of the fraction, performance of the wheat product is required which is the nominator of the fraction and the amount of the performance of the products was calculated using statistical letters and were inserted into the descriptive table related to the towns of Hamedan province and were turned to raster using convert features to raster, and the place extension map of products performance was calculated accordingly. (Fig. 4)

Finally place extension map of the actual evapotranspiration was overlaid by raster calculator performance with the place extension map of experimental performance and the final place extension map of water use productivity of wheat product throughout Hamedan was gained. (Fig. 5 and Fig. 6)

3. Results and Discussion

Fig. 1 presents the trend of time changes of the standardized precipitation index during one statistical period as a sample for Nojeh station. The studies resulting from calculation of SPI index for all the existing stations throughout the region show that in general during the recent years (10 years), the region has faced the drought conditions in 1999 (C1) and humid conditions in 1992 (C2) and normal conditions in 1989 (C3).

Fig. 2, it shows statistics of water use productivity and comparison between them throughout the region for three conditions C1, C2 and C3.In accordance with the results of Fig. 2 at condition C1, maximum of water consumption productivity in territory is 0. 67 Kg/m^3 that in sample form is according to Fig. 5 of the south and southwest regions and has higher water consumption productivity in comparison to the northern regions of the country. Also according to Fig. 6, most of the region has 2nd class productivity (0. 7-1).

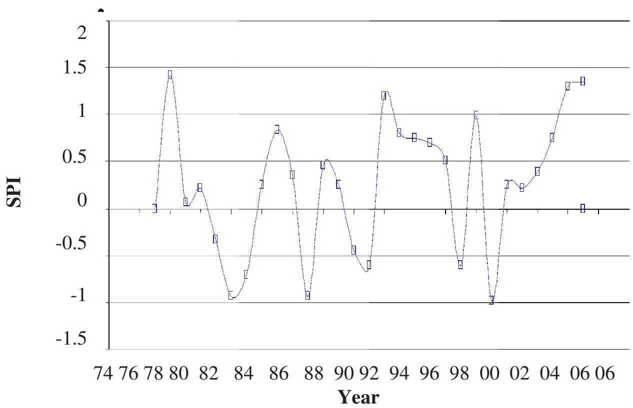

Fig.1: Chart of time series of standardized precipitation index (SPI)

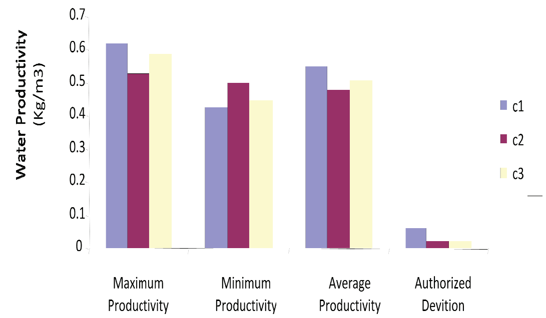

Fig.2: Chart to compare water consumption productivity statistics throughout the region

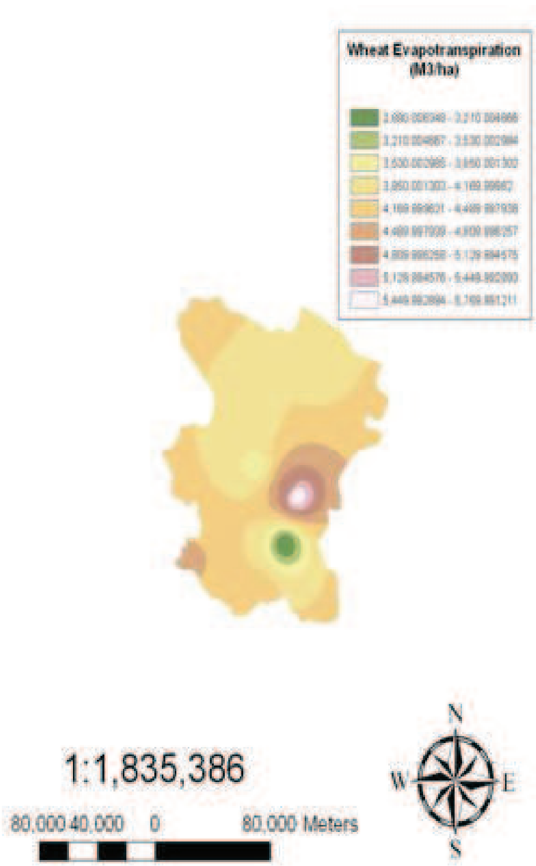

Fig.3: Location extension map of Evapotranspiration of wheat

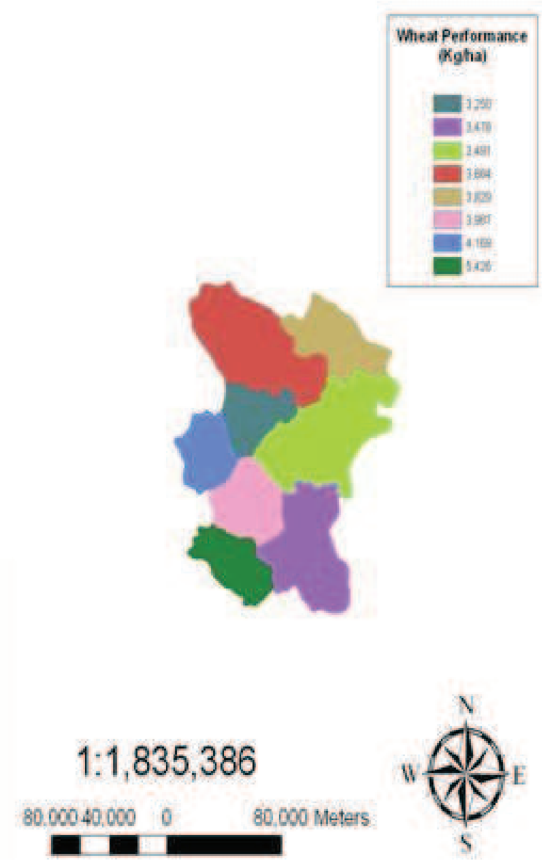

Fig.4: Location extension map of wheat performance

Under dry conditions such as C1 condition, contrary to what it seemed in the beginning, the average and maximum productivity stood at a higher level in comparison to the other two conditions that were of higher quality in comparison to condition C1. But as far as minimum productivity was concerned, the territory had minimum higher productivity under more humid conditions in comparison with dryer conditions.

Considering Fig. 5, it could be understood that the central part of Malayer and all the towns of Nahavand city possess the highest productivity throughout the province as well as the northern part of Malayer and the south of Hamedan that has the minimum productivity and the more we distance from these two parts, the more the productivity will be.

These two regions are also shown in classified classification in yellow (Fig. 6).
Most of the province is in blue which shows average productivity and we do not see the excellent conditions throughout the province and the production rank of 7 in the country is a manifestation of this issue.

4. Conclusions

Since the time and location dimensions were studied simultaneously, combination of these two factors resulted in more effective analysis and a more comprehensive understanding of the region to plan and make decisions; therefore, more information regarding the water storage techniques in agriculture will be made available to us.

It seems that water use productivity shows sensitivity as far as sun radiation and location changes are concerned.

The change of cultivation pattern and use of irrigation systems under pressure could be a suitable solution to increase the water use productivity.

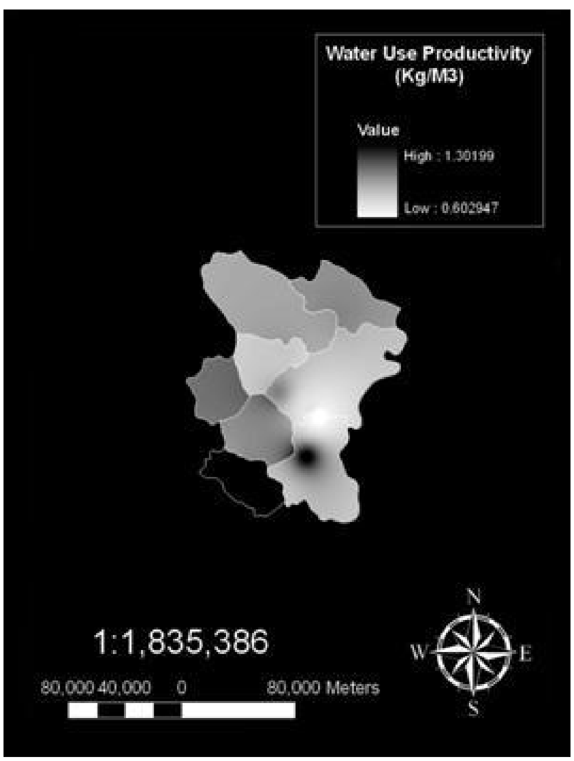

Fig.5: Location extension map of water use productivity of wheat (Stretched classification)

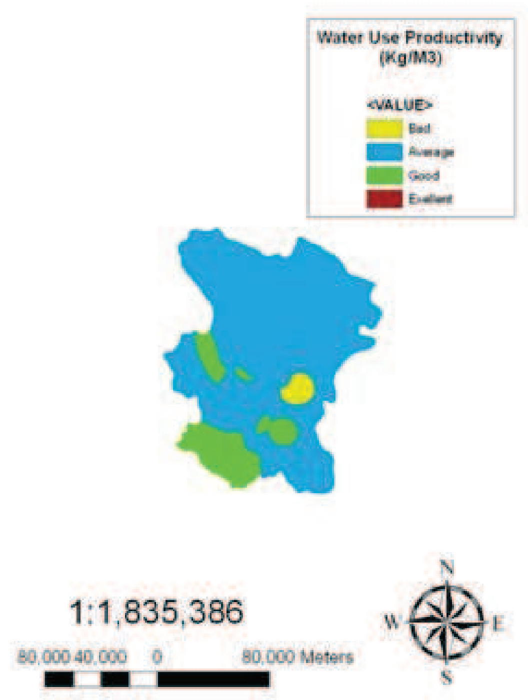

Fig.6: Location extension map of water use productivity of wheat (Classified classification)

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