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Fenugreek a multi-purpose and climate resilient crop for the low input agriculture system of South Asia

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Fenugreek (*Triginella foenum-graecum* L.), an important but less known ingredient of the globally famous South Asian curries is an annual legume crop and a traditional spice. Widely cultivated across South Asian nations as spice is more well known in other parts of the world as an annual forage legume crop. India is the largest global producer of the crop. The herbaceous plant has indeterminate growth habit with trifoliate leaves and legume pods containing 10-20 golden brownish seeds. This plant species has been used both in Ayurveda and Traditional Chinese Medicine in treating a number of human diseases. Both leaves and seeds have rich medicinal properties due to presence of steroidal sapogenins, alkaloids, complex carbohydrates (galactomannan) and essential amino acids (4-hydroxy isoleucine). Due to the presence of such important phytochemicals the seeds have been fund to have significant properties in reducing blood sugar and blood cholesterol levels. As such in addition to its traditional use as a spice and forage crop, the plant has attracted the pharmaceutical, nutraceutical and functional food industries. Semi-arid and drier parts of Bangladesh will be suitable for cultivation of this crop that has huge economic demands in the international markets. Furthermore, being legume it can fix nitrogen into the soil and hence useful as green manure and can be incorporated in any existing crop cycle of the region to prevent depletion of useful soil nutrients. It is also attractive for Organic Agriculture as well as in the process of reclamation of agriculturally unsuitable lands due the ability of enriching soil through natural nitrogen fixation with initial use of some commercially available nitrogen fixing microbial powder. The crop is also low in its water requirement and with global Climate Change impacting all the nations across the globe considered as a climate resilient water conserving crop suitable for the low input agricultural system of South Asian countries like Nepal, Bhutan, Afghanistan and Sri Lanka; and for poor local farmers who cannot afford big investments for industrial agriculture. There is need for popularizing a multi-purpose as well as economic and ecologically potential crop like Fenugreek (locally known as 'Methi') in South Asia. The crop could bring real economic benefits for the poor farmers of South Asian nations.

***Photo credit:* S. K. Basu**

Assessment report on the vulnerability of the Moghan plain, Iran

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Underground water is one of the most valuable as well precious natural resources in the world. Currently significant part of the Iranian water consumption, especially drinking water is supported through underground water resources. Without proper recognition or understanding of the vulnerability of underground water streams can cause serious pollution and often make these resources temporarily or permanently unavailable for human consumption. The reuse and cleaning of such polluted resources involve both time and expenditure. Recent human activities have created such a vulnerable environment that the underground water, as an important natural resource has been seriously exposed to both industrial as well as agricultural pollutants. Based on the diversity of anthropogenic usages and local economic needs in Moghan plain aquifer of Iran; agricultural activities like irrigation has been developed in the region with possibility of underground water contamination as a result of indiscriminate application of chemical fertilizers and toxic synthetic pesticides.

The concept of vulnerability was first conceptualized in France in the late 1960s to provide mass awareness about underground water pollution. Vulnerability can be described as the possibility to permeate and distribute pollutants from earth's surface to underground water system. Aquifer vulnerability, shows its' force for permeating and distributing pollutants from earth's surface to the underground water system. So that the pollution generated in the earth's surface can reach the underground water and contaminate it. Vulnerability is a kind of relative feature which is dimensionless and cannot be measured and is dependent on the aquifer characteristics, geological environment and hydrogeology. Different methods have been proposed for vulnerability evaluation, which can be classified as processing techniques, overlapping index method and statistic index method. The processing methods use simulation models to predict the movement of pollutants. Statistical techniques use correlations between the location variables and the amount of pollutants which are present in underground water. Overlapping index method integrates the parameters which control the pollutants movement from the earth surface to saturated zone and defines a vulnerability index for different positions in a region.

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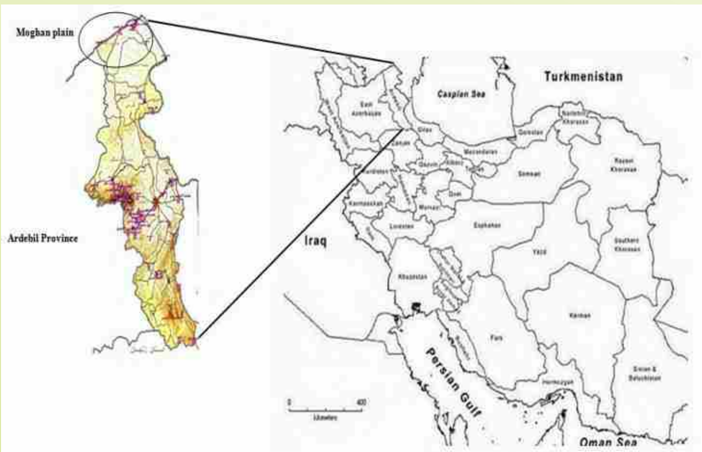
In the overlapping index method, to some extent selecting numerical values of the parameters is technical; and these methods cannot be used as an accurate method for proper prediction. The simplicity of the preparation of the required information on the regional scale is the main advantages of this method. In all the methods, the aquifer vulnerability is estimated based on the contamination transmission from the earth's surface to the aquifer layer. One of the most common methods for evaluation of the aquifer inherent vulnerability is the Drastic method that has many applications. This method has been used in different parts of the world such as South Korea, UAE, India, Algeria, Portugal, Japan, Jordan and Iran.

In this study, the Drastic model has been used for investigating underground water vulnerability and GIS environment is used to prepare the map. The objective of this study has been to prepare a vulnerability map and detect areas with strong force for polluting underground water table in the studied area. Due to the importance of underground water resources for drinking, agricultural and industrial purposes, aquifer vulnerability study and protection of these areas are necessary for the development and optimal management of local water resources for future generations and economic developments.

The Moghan Plain (the confinement of irrigation networks) of Iran which is located north of Ardebil province; with eastern lengths between 25'-470 and 25'-480 and northern width between 25'-390 and 42'-390. This plain is about 944 square kilometers in area which is a geographical section of Pars Abad city and Aslanduz Vile Savar. The average annual precipitation is 299 mm and the average annual evaporation is about 870 mm. The slope of the Moghan is towards north and east and it's amplitude from the Caspian Sea level is 52 m and from free sea level is 24 m. The climate of Moghan plain is semi-arid in nature; and moderate with hot and relatively dry summers



and mild winters. The Moghan region is covered with micro grain alluvial sediments. The surface soil up to the depth of 6 m composed of silt and silt-clay-loam. Micro grain sediments gradually convert to relatively hard sandstone and Konglomera; which are the main constituent materials of the aquifer. As irrigation is developing in the area and underground water is extensively used for drinking purposes; it is likely that underground water may get polluted due to the over application of synthetic chemical fertilizers and pesticides.

Vulnerability zoning is carried out in GIS environment. For this purpose, the data were entered into GIS databases. In this study, different databases such as topographic maps with the scale of 1:50,000, geological map with the scale of 1:100,000 soil map, meteorology statistics, hydrology, underground water level, pumping tests results, drilling logs, observation, exploration and exploitation wells, geophysical maps and water consumption statistics were taken from the Water Organization in Ardebil province. The most simple and common method for evaluation of underground water vulnerability to pollution is using a weighting model. In these methods, the criteria are rated according to their impact on underground water pollution. The most common method for evaluating the intrinsic vulnerability of the aquifer is the Drastic method, designed by the National Underground Water Association in cooperation with the United States Environmental Protection Agency. In this method, seven measurable factors, or characteristics are estimated for the hydrogeologic system.

These factors include underground water depth, recharge network, aquifer media, soil type, topography, impact of unsaturated zone and hydraulic conductivity. In this method, the coefficients can be changed according to the characteristics of the studied area. These factors are estimated numerically and to each of them with respect to their potential pollution, a rate of 1-10 is assigned; where 1 is lowest and 10 is highest risk of underground water pollution. Each of these characteristics according to their ability in transmitting pollution to the underground water, are multiplied to weight coefficients which is determined by qualitative criteria (from 1-5) judged by the researcher. The Drastic method uses the most efficient characteristics in vulnerability, so it decreases the possible uncertainty of different criteria.

The purpose of underground water vulnerability is providing a map and detecting the regions with high vulnerability. Using the appropriate method for preparing a map of vulnerability zoning in an area is dependent on the presence of the data and their distribution; and the hydrogeology position, the scale and the map's target. For preparing vulnerability zoning maps, GIS environment can be used. The Drastic model was not first designed for use in GIS, but investigations showed that running this model has many advantages. By using spatial analysis facilities which is available in GIS, information layer is made based on seven Drastic components. When the Drastic values are shown through GIS, the spatial relation between the implementation of land management and underground water vulnerability becomes evident.

Vulnerability evaluation by Drastic method

Layer of underground water depth (D): The depth

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of underground water is related to the distance which pollutant travels to reach the aquifer. It is clear, greater the depth of the underground water level, it takes more time for the pollutants to reach the aquifer. There is the possibility that the pollutants can spread, dilute in the soil or be absorbed. Underground water depth has a direct relation and significant impact on the aquifer pollution. So the weight of 5 is considered for the water depth. Statistical data of the depth of underground water is obtained from observed wells in the aquifer. By using monthly depth observation of underground water in the studied wells in Moghan plain and verify data and correct it if necessary by using Kriging interpolation; the co-value map of the underground water depth is obtained.

Recharge Network layer (R): One of the main factors for transmission of pollutants into the ground is the vertical movement of water which wash pollutants with itself and carry it as a solution or a colloid or suspension into the ground. Intensity and transition of soluble materials is strongly depended on the intensity and vertical movement of water into the earth. To prepare recharge layer, Piscopo method (2001) was used and adjusted according to the Aler ranking. In this method by using the slope, precipitation and soil permeability, the recharge potential of the area is obtained. By using 21-year statistics of precipitation in two stations of Pars Abad and Aslandooz; and the interpolation of co-precipitation lines and converting them to raster format in the GIS environment. The digital precipitation model is easily obtained and the co-precipitation map of the plain is drawn. According to the following formula: Recharge Rate = Slope Percent + Precipitation + Permeability

Aquifer media (A): Aquifer media represents the damping characteristics of the aquifer constituent materials. This feature is indicative of the dynamic and movement rate of contamination among the aquifer components. The information about the aquifer media is obtained from subsurface explorations (log, exploratory and piezometric drilling, exploitation wells), geophysical and

geological explorations in the area. In Moghan plain, the map of logs location, exploratory drilling, and deep observations are provided and based on the exploratory studies and Drastic standard method, aquifer media properties are valued. The weights of these three layers are proposed equal to 3.

Soil layer (S): Soil layer with a thickness about 0.5-2 m is a very

microbiologically active area. Due to the relatively high microbial activity, the presence of organic matter and plant roots, soil layer has high potential for elimination and reduction of the contaminant's concentration. In this study, the soil map of the region which is prepared by the Water and Soil Institute have been digitized. This layer is related to the changes in surface slopes. It is supposed that in the lower slopes soluble pollutants have greater opportunities for permeation. So the areas with lower slope, has a higher ranking in the model. Higher slopes make soluble materials to flow and permeate less.

Topography (T): In the Drastic model, topography lines are zoned as percentage co-slope regions. It is assumed that 0-2 % slopes has the highest permeability and it's ranking is equal to 10. Areas with slopes over 10 % have the lowest rank, because they have the least permeability. Another effect of the slope is in the development of the soil so that the top surface layer thickness becomes less in higher slopes. For Moghan area, the slope maps are obtained by using digital maps of military geography organization with the scale of 1:50,000 for this purpose, topographic maps are converted to digital elevation model in Arc-GIS software; then slope map is calculated and extracted from digital elevation models.

The effect of unsaturated zone (I): This layer is related to the soil type, which begins from the surface soil zone and continues to the static level. In terms of water, they are unsaturated or saturated discontinuously. In the Drastic model, it is supposed that the environment and condition of unsaturated region have a significant effect on the pollutant materials, because in this region, they find the opportunity to be absorbed or diluted before getting to the static level. The information collection of unsaturated region is the same as aquifer environment. The only difference is that the grading and characteristics of sediments between underground water surface and the ground surface is considered.

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Hydraulic conductivity layer (C): This layer is related to the permeability of the aquifer or the aquifer material 's ability to transmit water or soluble materials. In hydrology problems, the hydraulic conductivity is shown with K and its dimension is the type of speed .Underground water flows under the environmental hydraulic slope. Hydraulic conductivity is the controlling factor of the movement and the retention time of pollutants from the point where entering a level can cause higher pollution potentials. So, hydraulic conductivity information is achieved via pumping test calculations. In the areas where the pumping test is not conducted; based on typical values and similar structures, types and textures of sediments forming the aquifer, hydraulic conductivity is estimated.

The combination and integration of layers: In GIS for combining the raster layers, overlapping function were used. Since the used data were converted to raster format, so the overlapping function was used for this purpose. This function combines the data either mathematically and by weighting. As all layers have special weights in the Drastic model for combination and integration of data, weighting overlapping function were used through Raster calculator menu in ArcGis software. For this purpose, all the layers were defined with percentage coefficients, then integration of layers were carried out. According to the obtained zoning map, around 10% of the plain is placed in the area without the risk of pollution, 20 % of it is placed in the range with very low vulnerability and 70 % of it is placed in the area with low vulnerability.

On the basis of the results of modeling the vulnerability of Moghan aquifer we conclude that the northern half of the region has a higher vulnerability potential compared to other parts of the plains. Protection of these areas to prevent pollution of water resources and optimal management of water resources is therefore essential. We therefore suggest since removing pollution from underground water resources is too expensive, zoning can be used as an effective tool and help make necessary decisions for proper land use and management of Moghan plain aquifer. These include changing the usage pattern of the lands, managing agricultural fertilizers and pesticide usage properly and sending civil waste water to safer places to avoid contamination of the underground water resources.

Photo credit: **Y. Motayagheni**

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