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A Semi-Detailed Technique for Soil Erosion Mapping Based on BLM and Satellite Image Applications

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ABSTRACT

An ever increasing population needs more energy and food to be provided from limited resources. Many different problems such as floods and droughts frequently occur and even happen at extreme values throughout the world, since the inherent capability of the resources is not evaluated properly. Soil erosion, as one of the major types of land degradation, is supposed to cause serious problems for future and even present generations. However, evaluation of the magnitude and spatial distribution of fundamental types of soil erosion i.e. sheet, rill and gully erosion is an important task to be conducted in developing countries where the necessary bases for development are required. An attempt has been made in the present paper to introduce a technique through which the condition of soil erosion is defined and mapped in the study area. All available and acceptably accurate information, such as the geologic sensitivity of the area to erosion, the land type and slope maps, are required for determination of homogeneous work units using overlying. The present character of soil erosion in the field is then evaluated by filling out the revised questionnaire forms adjusted on the basis of criteria mentioned by United States Bureau of Land Management (USBLM) and the final classification of each type of erosion is made according to the sum of scores obtained by each work unit. Finally, the overall situation is generalized in the fractional form. The presented technique has been implemented for more than 6 million hectares of the area of Iran and was able to reflect the governing conditions well and the results should be applied in the management of natural resources to achieve sustainable utilization. For the present study and for demonstrating the details of methodology, a small watershed located in the Markazi large watershed of Iran, known as Barahmoom, and comprising 4236.2 ha was selected as a case study. The presented soil erosion mapping technique can be applied for areas where only basic or very little data and information is available.

Keywords: BLM, Markazi Province, Soil Erosion Mapping, Remote Sensing, Water Erosion.

INTRODUCTION

A proper evaluation of the capability and suitability of the resources, particularly natural renewable ones such as soil, water and vegetation cover, is an important basis for facilitating appropriate planning and management. The executive plans may be designed to be implemented at local, national, regional and even international levels which affects on the accuracy and speed of the projects. Causes for stressed natural systems are numerous among which soil erosion may be flagged as the major problem about which very few studies have been conducted on the linkage between effective factors, and there is an urgent need to look into this (International Task Force, NRCS, 1997). Soil erosion caused by water is also an increasing global problem in terms of extension and severity as well. Land use and soil conservation planning for large areas requires erosion risk maps, which are typically created using erosion models. Soil erosion mapping is an important aspect of monitoring environ-

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mental changes. Thinking about integrated development and construction activities and their effects on regional environment, soil erosion studies are mainly aimed at analyzing the erosion phenomenon, classifying soil erosion types and determining its erosion degrees to help to develop for steps prevention and cure (Zengxiang *et al.*, 1996). Therefore, it is extremely important to recognize watersheds damaged by active erosion so that timely steps can be taken to adjust land use, and to initiate corrective vegetative and small engineering measures to achieve sustainable development. Assessment of the magnitude and extension of each major type of soil erosion is something that has to be conducted in a relatively accurate manner to be applicable for other specialists for defining pertinent projects.

As one of the pioneer studies in the field of soil erosion mapping, Lantieri *et al.* (1990) conducted a pilot study in the State of Paraña, Brazil to define an operational method for erosion susceptibility mapping at scales between 1:50,000 and 1:100,000 to assist the planning of a World Bank Land Conservation Project. In continuation, soil erosion mapping was undertaken using Universal Soil Loss Equation and GIS by ACRS (1994). Suri and Hofierka (1994) presented a possible way of identifying water erosion on large agricultural areas that combines remote sensing and GIS techniques. An unsupervised classification of SPOT XS data and a topographic potential for erosion and deposition computed within Geographic Resources Analysis Support System and Geographic Information System (GRASS GIS) have been compared and the results analyzed. This combination improves the accuracy of mapping this phenomenon and may be useful in spatial extrapolation of field measurements. Zengxiang *et al.*, (1996) have combined remote sensing and GIS with experts' knowledge in order to understand the objective and overall states of soil erosion in real time and get digital results in Central Tibet. Vrieling *at al.* (2001) described a new qualitative methodology for mapping soil erosion risks over large areas of Puerto López municipality in the Colombian Eastern Plains, called Qualitative Erosion Risk Mapping (QUERIM). The QUERIM is a flexible method that uses decision trees to assign ratings to the erosion-controlling factors. These decision trees, constructed using expert knowledge, reflect the important characteristics influencing erosion risk within a specific region. Ratings made for soil erosion-controlling factors are combined at every location to obtain potential and actual erosion risk maps. The erosion risk maps obtained with the help of QUERIM showed good agreement with field observations. Different approaches followed by a few countries such as the USA, China, Argentina and France were scrutinized and their applicability was then assessed in consideration of the availability of the information required and the feasibility of the techniques. The quantitative mapping of soil erosion is usually conducted by erosion or sediment estimation models as Stefanovic *et al.* (2004) have done for Yugoslavia using EPM. These models are often developed for different regions than those in which they are applied. However, more field data should be gathered for model calibration and, ultimately, a better evaluation of any method should be undertaken. It can be said that a simple qualitative approach can be more effective in erosion risk mapping than the use of models that were not developed for the region to which they are applied (Vrieling *et al.,* 2001). Methods and techniques either developed for other countries or suggested by related specialists cannot be often applied because of the unavailability of required data and information or difficulties in obtaining necessary inputs. Therefore, a substituted method or approach needed to be innovated in the field of soil erosion studies, which would be applied with the help of available and accessible information by inexperienced experts and within a short period. The aforementioned issues are certainly more considerable in developing countries owing to the need for development on one side and the lack of sufficient financial support and inaccessibility to wellsuited technologies on the other side which itself may cause many unwanted and unexpected problems. To get an idea of the severity and extension of water erosion in Iran and to overcome encountering soil erosion-related problems as well, a soil erosion mapping project was considered by the Bureau of Investigation and Evaluation of Watersheds, Ministry of Jihad-e-Agricultural of Iran, since ten years ago. The present research therefore seeks to introduce a technique which can be applied in un-gauged watersheds, mostly in undeveloped or developing countries.

MATERIALS AND METHODS

Considering the lack of sufficient data and information associated with soil erosion in Iran, the features and forms of erosion, i.e. visual indicators, and their distribution and intensity was focused on as an applicable concept to map soil erosion. The present features of soil erosion were supposed to be the main factor affecting on the amount of soil erosion which could have been applied to achieve the purpose. Likewise, simple visual indices and short term evaluations are not a replacement for more precise, long term surveys such as reservoir sedimentation surveys, plot scale studies, sediment runoff monitoring, where such are required (FAO, 1976). Since the application and combination of remote sensing and GIS along with some other available information could be applied in most developing countries for natural and environmental investigations (Lunden and Nordstrom, 1990; Pilesjo, 1992; Mitasova *et al.*, 1993 and Mitasova *et al.* 1996), the same approach was employed to develop an appropriate technique in water erosion mapping in Iran. The set of initial available information was the following.

-Land capability map with a scale of 1:250000.
- Lithologic and formation map with a scale of 1:250000 and 1:100000.
-Slope steepness map with a scale of 1:250000.
- Aerial photographs with a scale of 1:50000 and 1:20000.
- Satellite images of Landsat with a scale of 1:100000.

All of the above information is available for the whole of the country and therefore any project based on them could be implemented. The project started from a pilot area located at the center of the country in Isfahan Province, consisting of an area of more than four million hectares.

For the purposes of the present study and to demonstrate the details of processes a small watershed located in the Markazi large watershed of Iran, known as Barahmoom, with an area of 4236.2 hectare and draining into the 15th Khordad Dam was selected. The study area extends from 49°52´38″ to 49°52´51″ E longitude and 35°15´20″ to 35°15´22″ N latitude. The maximum and minimum (outlet) elevations of the study area are respectively 2322 and 1890 meters above mean sea level. The Barahmoom watershed has a drainage density of 3.61 km per km^2. The entire watershed is divided into three sub-watersheds according to the drainage pattern. Some of the important physiographic specifications are presented in Table 1 shown below (Sadeghi, 2002).

The first three maps land capability, lithologic and formation and slope steepness were firstly overlaid on each other to obtain

Table 1. Some physiographic specifications of the study area.

Series	Area (ha)	Area (%)	Perimeter (km)	Bifurcation ratio	Slope (%)
Sub-wat. 1	659.4	15.57	13.91	1.15	19.26
Sub-wat. 2	1858.1	43.58	23.47	3.79	13.55
Sub-wat. 3	1718.7	40.57	20.14	2.68	13.77
Watershed	4236.2	100.00	32.52	1.85	14.52

relatively homogeneous units which could be used as defined area for the commencement of the study. Then, the other two final pieces of information i.e. aerial photographs and Landsat images were used for checking the boundaries of the units and splitting them into more units, if necessary according to optical vision, and therefore the accuracy of the study would be increased.

In the next step, the US Bureau of Land Management (USBLM) reconnaissance procedure based on the seven visible soil surface features viz. soil movement, surface litter, surface rock, pedestalling, rills, flow pattern and gullies was selected as a base for the qualitative assessment. Each feature is assigned a numerical value expressing the degree of soil movement occurring through erosion processes. The first five factors score from zero to fourteen, while the two last ones end in fifteen and are categorized entirely into five classes. The scores assigned to each factor were summed up and then classified from total low numbers 1-20 (very little erosion, A) to a maximum total of 100 (very active erosion, E). The data available and the technical knowledge on soil, vegetation, geology, etc. were also subjectively taken into account. That means some of the factors might not be "potentially present" e.g. a situation where no rocks are in the soil profile and could not exhibit the "surface rock" factor. This classification shows the overall condition governing semi-homogeneous polygons whereas the classification of major types of erosion (sheet, rill and gully) were also required for prioritization purposes. Scrutinizing the table mentioned above shows that the first four factors of soil movement, surface litter, surface rock and pedestalling, fifth and sixth factors, i.e. rills and flow patterns, and the final one (gullies) refer respectively to the situation of sheet, rill and gully erosion.

The USBLM procedure was then applied for all polygons in the study area and adequate numbers of questionnaire forms were filled up in the field until the description of erosional conditions of polygon seemed assured. The number of the forms might be more than the number of the polygons, since for each one, more than one questionnaire might be filled up based on the proportional variations of the soil erosion features. In other words, one polygon might be broken into many sub-areas having different classes of soil erosion type and intensity. The result of evaluation in each sub-area was ulti-

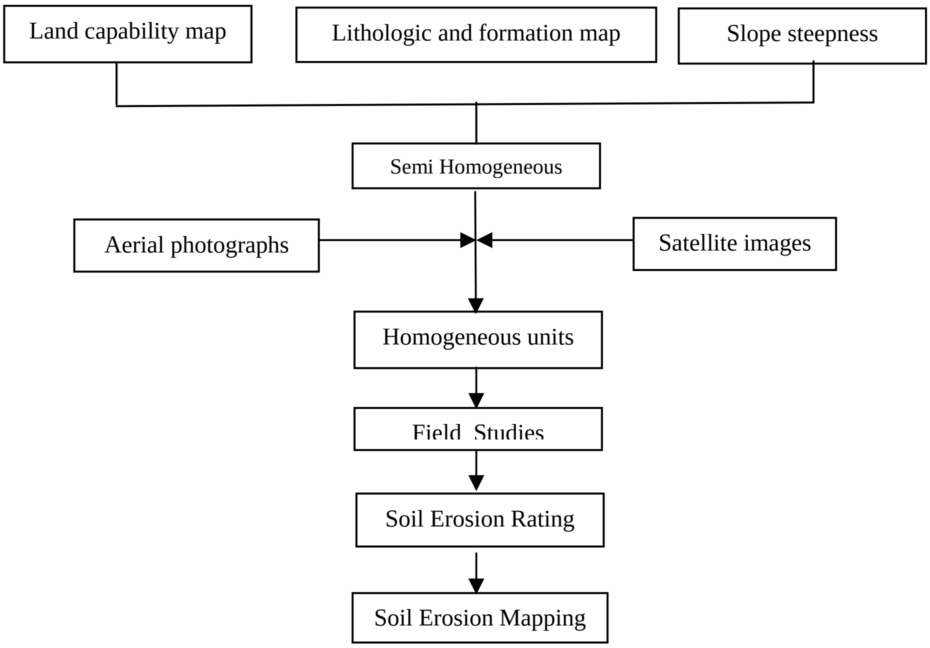


Figure1. Flowchart of soil erosion feature mapping in Iran.

mately demonstrated in the fractional form as shown below:

$$\text{Soil Erosion Feature} = \frac{\text{Land Type, Geo log ic Formation Slope Class}}{\text{Overall class, } S_{\text{Intensity, Area}}\ R_{\text{Intensity, Area}}\ ,\ G_{\text{Intensity, Area}}}$$

where S, R and G stand for sheet, rill and gully erosion, respectively. Overall class is shown in the capital letters of A to E. Intensity is also classified into three groups shown by numbers 1 to 3 in the sub-script based on the average scores obtained by each type of erosion. The area covered by each type of soil erosion is also reflected in numeric form as 1 to 4 denoting areas less than 25, 25-50, 50-75 and above 75% of total area of study polygon, respectively. The general design was followed as shown in Figure 1.

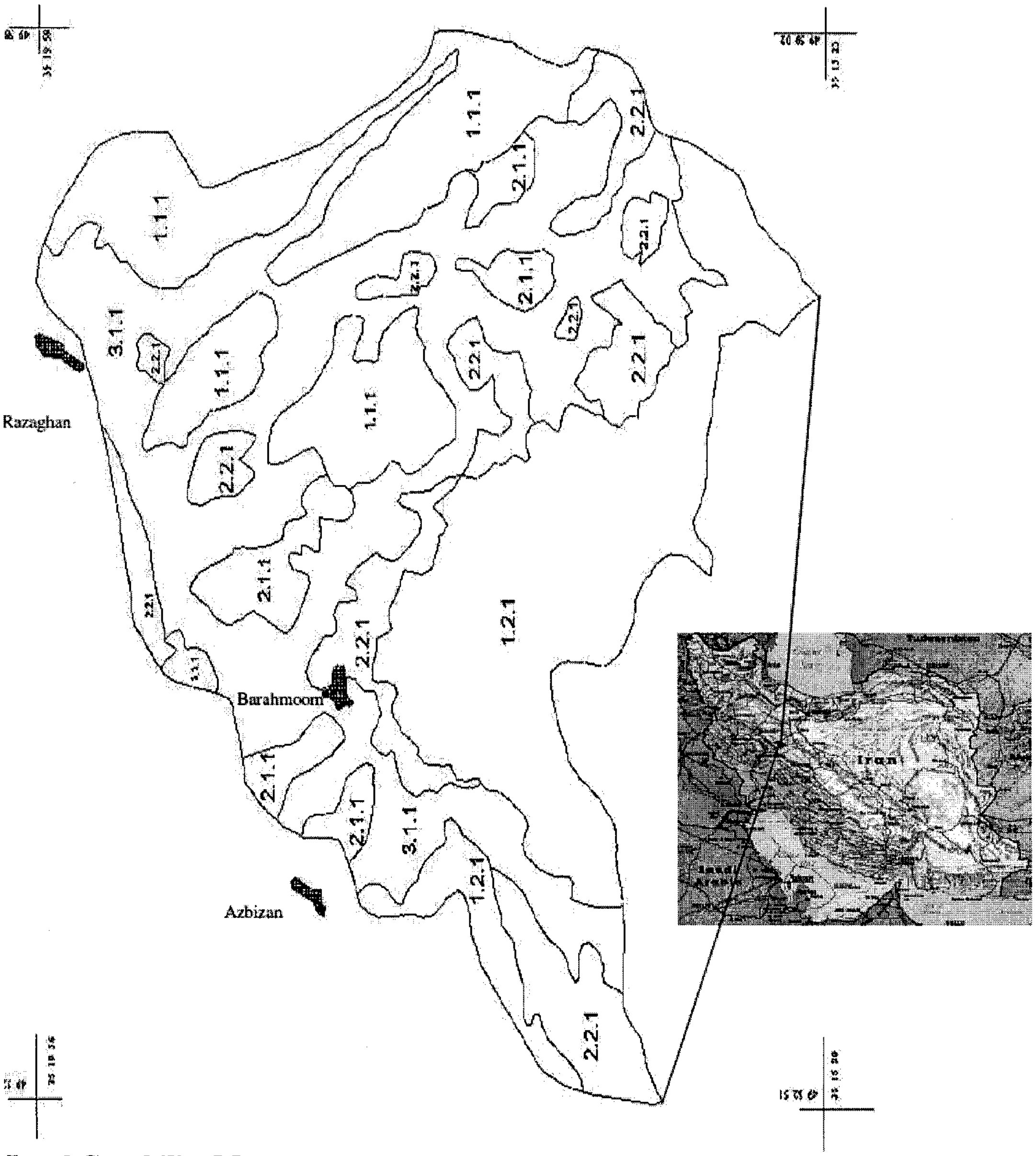
RESULTS AND DISSCUSSION

The USBLM technique described above was applied in the Barhmoom watershed in Markazi Province (Iran) with an area of 4236.2 ha. All the required maps, including land type (Figure 2), geologic formation and relative sensitivity of the formation (Figure 3) and a slope map were provided for the study area and appropriate corrections were made with the help of satellite images and field surveys as well. Necessary explanations and descriptions have been given in figures legends. The maps provided were converted to the same scale of 1:50,000 and overlaid on each other to discover the relatively homogenous polygons. The land types map was extracted from the land capability map and set as the base map. The geologic formation map was consequently overlaid and a semi-detailed map was obtained. The slope map of the study area was then overlaid on the two previous maps and the detailed map was ultimately prepared. All this overlaying process was conducted on transparent paper. The final map was then considered as the work unit map and was taken to the field and at least one of the aforesaid forms was then filled in for each uniform area in the homogenous polygons. The general situation of each study unit was then evaluated in terms of erosion features and demonstrated in a symbolic format. Adjacent areas with the same formula were then combined together. The nominator of the fraction was also eliminated for better clarity and simplicity. The erosion map developed for the study area is shown in Figure 4.

The results of the study show that there are nearly 19 erosion hazard categories in terms of soil erosion features but the entire watershed was basically categorized as class B, i.e. a weak class, except one small polygon in the north-east part which stood in class A. Different types of soil erosion were recognized, more or less, at a low severity and occupied almost 25 to 50% of the study polygon. Scrutinizing the soil erosion feature map shows that the area located in the western parts of the watershed have the worst erosional conditions and these coincided with the more susceptible geologic formation and steeper slopes. It helps local managers to avoid aggressive utilization of natural resources in such types of area due to the high potential level of soil erosion. It may also help decision-makers to evaluate the natural conditions of the resources, to designate the proper level of utilization as well as to allocate enough investment to the area to achieve sustainability.

CONCLUSION

Soil erosion mapping would facilitate the development of a suitable plan for the proper utilization of natural resources with the goal of promoting in sustainable development. The semi-detailed technique proposed for soil erosion mapping based on a conjunction of BLM with satellite image interpretation is a user-friendly and applicable method through which the erosion risk of an area

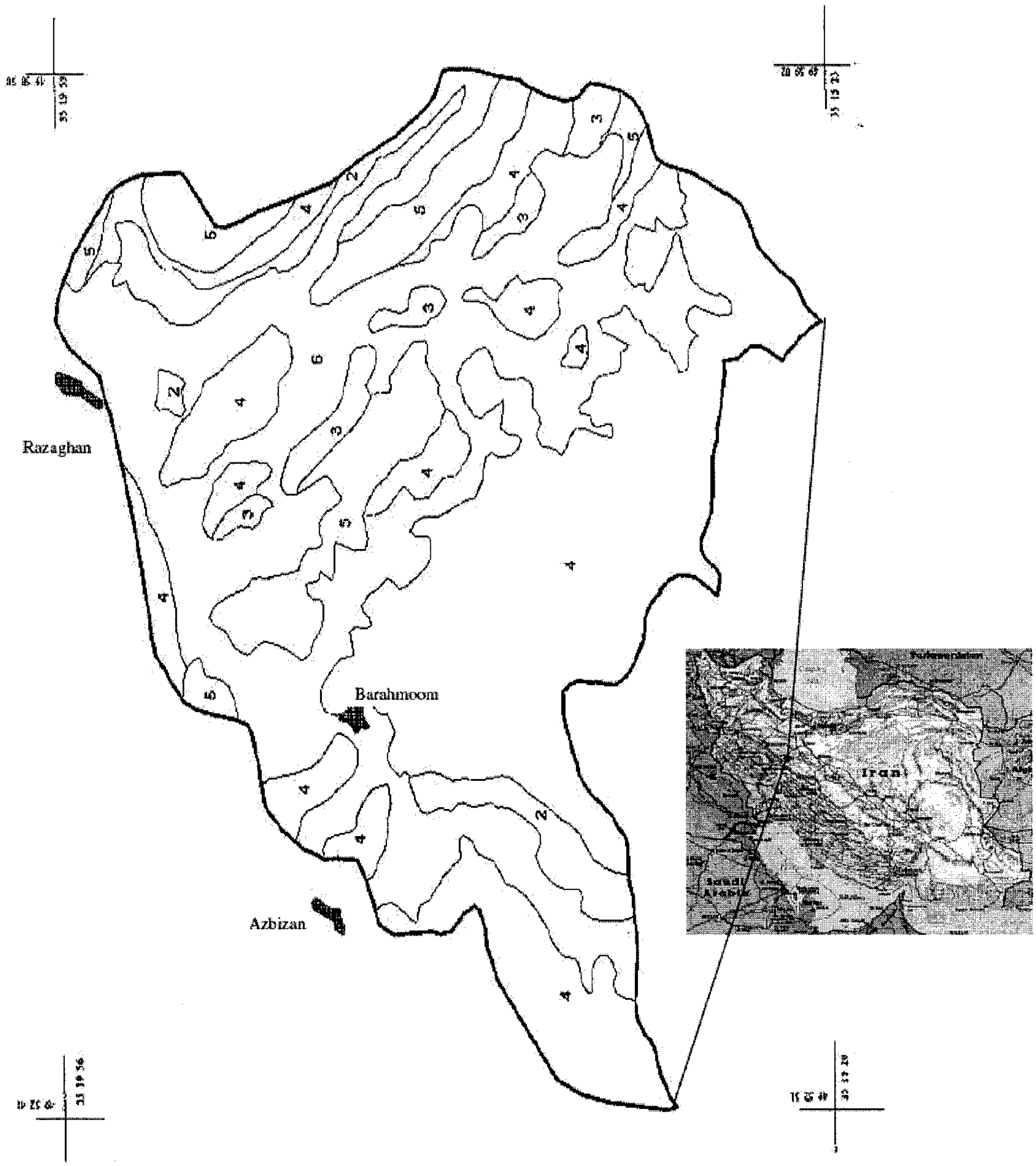


Land Capability Map

Legend
N
Watershed Boundary
Urban Area
Scale: 1:50000

Land Units	Specifications	Soil Properties	Land Use
1.1.1	Mountains, Low vegetation cover, Slope: 40-70%, Elevation: 2050-2250 asl	Shallow soil, Heavy texture (Clay Loam) Lithric Lepthosols	Rangeland
1.2.1	Mountains, Low vegetation cover, Slope:20-50%, Elevation:1650-2100 asl	Shallow soil, Gravel and Heavy texture, (Clay Loam) Lithric Lepthosols	Rangeland
2.1.1	Low to high elevated hills with sharp crest, Slope:8-20%	Shallow soil, Heavy to medium texture, Lithric Lepthosols	Rangeland
2.2.1	Relatively high elevated hills with round crest,	Semi deep soil, Heavy texture, Typic xerorthents	Dry land, Rangeland
3.1.1	Traces, Plateaus, Slope: 3-5%,	Deep soil with gravel, Medium to Heavy texture, Haplic calasols	Dry & irrigated land, Rangeland

Figure 2. Land Capability Map of the Barahmoom Watershed.

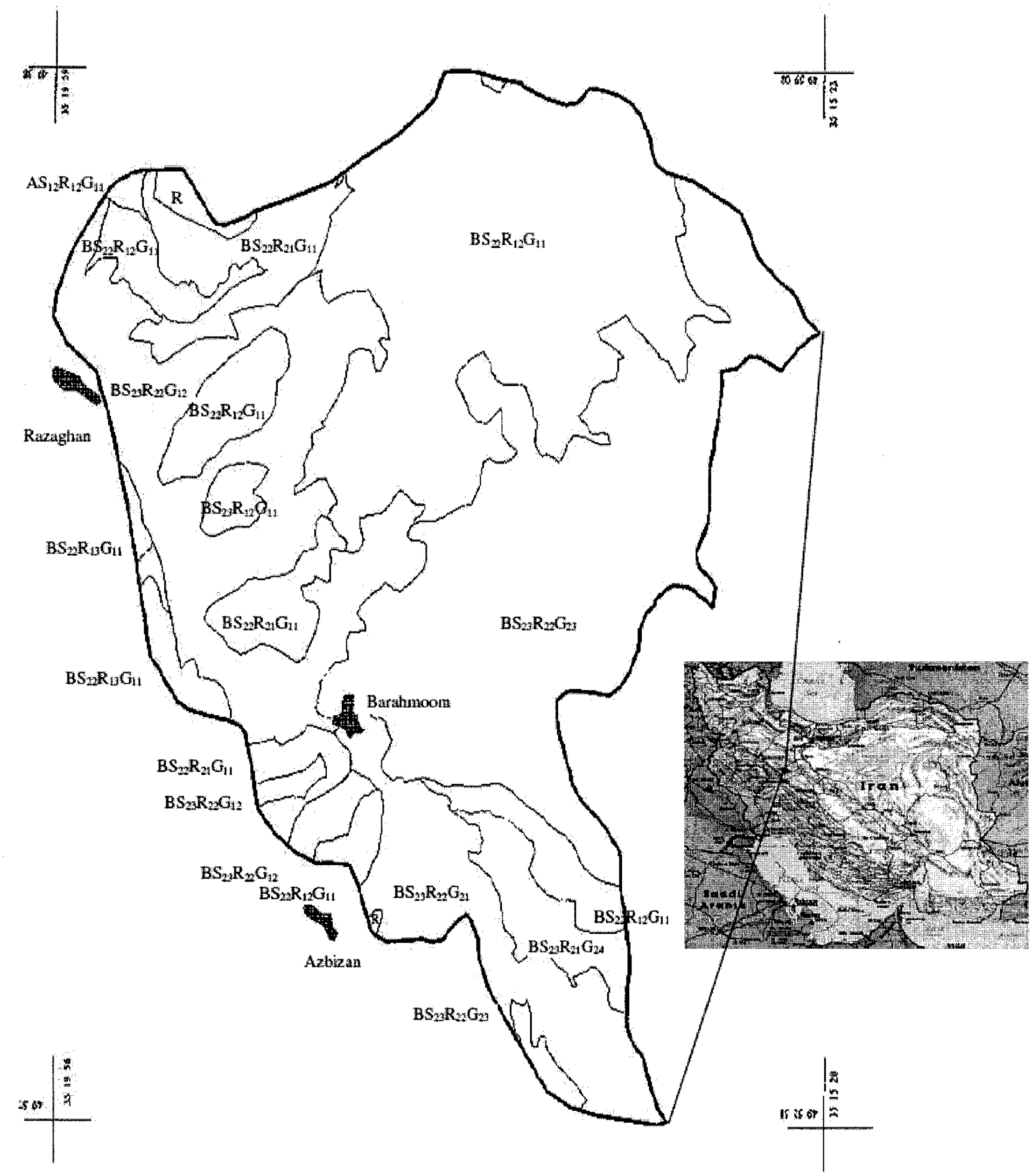


Lithology and Formation Sensitivity Map

Legend
N
Watershed Boundary
Urban Area
Scale: 1:50000

Degree of sensitivity to Erosion	Typical formation and Lithilogy
2	$E6^{ii}$- $E6^{hb}$- $E6^{tr}$
3	$E6^{da}$
4	$E6^{ad}$- $E6^{bd}$- $E6^{ig}$- $E6^{ta}$- E5
5	$E6^{at}$- $E6^{gt}$- OM^{1m}
6	Qt1

Figure 3. Lithilogy and formation sensitivity map of the Barahmoom watershed.



Soil Erosion Feature Map

Legend

N

Watershed Boundary

Urban Area

Scale: 1:50000

Soil Erosion Feature= *Overall class,* $S_{Intensity, Area}$, $R_{Intensity, Area}$, $G_{Intensity, Area}$					
Overall Class		Sheet (S), Rill(R) , Gully(G)			
Symbol	Class	Severity		Area (%)	
A	Stable	1	Very low	1	0-25
B	Weak	2	Low	2	25-50
C	Medium	3	Moderate	3	50-75
D	Sever	4	Sever	4	75-100
E	Very Sever	5	Very sever		

Figure 4. Soil erosion feature map of Barahmoom watershed.

faced with lacks of data and information can be evaluated. The method introduced in this study can therefore be used for soil erosion mapping of areas where detailed and accurate data on soil erosion and sediment yield measurements do not exist. Applying this technique may help designers, planners, decision makers and executive managers to visualize an appropriate idea about the inherent capability of the watersheds based on the present situation of their erosion features as a good indicator to reflect the interaction of entire forces governing the watersheds' outputs. The extension of the use of the proposed methodology along with the application of other similar applicable approaches is also suggested for other parts of the country to recognize the most extendable technique leading to a national soil erosion map. Regular updating of the methodology of soil erosion and mapping systems designed in the study areas is another recommendation for a better understanding of soil erosion processes taking place in the watershed system.

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REFERENCES

1. ACRS, 1994. Soil Erosion Mapping with Universal Soil Loss Equation and GIS, http://www.gisdevelopment.net/aars/acrs/1994/ts3/ts3001.shtml
2. FAO, 1976. Simple Visual Methods for Identification of Critical Watersheds. *Soil Conservation Guide,* **3**: 95-102.
3. International Task Force, NRCS, 1997. Newsletter of the International Task Force on Land Degradation, September 1997, No. 2,(http://www.nrcs.usda.gov/technical/worldsoils/landdeg/199709news.html).
4. Lantieri, D., Dallemand, J.F., Biscaïa, R., Sohn, S. and Potter, R.O., 1990. *Erosion mapping using High-resolution Satellite Data and Geographic Information System,* Pilot study in Brazil, RSC Series No. 56, FAO, Rome.
5. Lunden, B., Nordstrom, K., 1990. An Evaluation of Soil Erosion Intensity Mapping from SPOT Satellite Imagery by Studies of Colour Air-Photos and Top-Soil Content of 137 Caesium. *Uppsala Universitet Naturgeografiska Rapport*, **74**: 13-37.
6. Mitasova, H., Brown, W. M., Gerdes, D.P., Kosinovsky, I. and Mitas, L., 1993. Modelling Spatially and Temporally Distributed Phenomena: New Methods and Tools for Open GIS. *Proceedings of Second Conference/Workshop on Integrating GIS and Environmental Modelling*, Boulder, Colorado, U. S. A.
7. Mitasova, H., Hofierka, J., Zlocha, M. and Iverson, L.R., 1996. Modelling Topography Potential for Erosion and Deposition Using GIS, Int. J. *GIS*, **10(5)**: 629 - 641.
8. Pilesjo, P. 1992. *GIS and Remote Sensing for Soil Erosion Studies in Semi-Arid Environments- Estimation of Soil Erosion Parameters at Different Scales*. Lund University Press, Lund, 203 p.
9. Sadeghi, S. H. R., 2002. *Soil Erosion and Sediment Yield Study of Barahmoom Watershed, Markazi Province, Iran*. 20pp.
10. Stefanovic, M., Gavrilovic, Z. and Milojevic, M. 2004. "Erosion potential method" and Erosion Risk Zoning in Mountainous Regions, In: *Interpraevent2004 Proceedings*, Italy, May 24-28, 2004, **1(3)**: 281-290
11. Suri, M. and Hofierka, J., 1994. Soil Water Erosion Identification using Satellite and DTM Data. In: *Proceedings of EGIS/MARI'94 Conference*, Paris, France, March-April. 1994. pp. 937-944.
12. Vrieling, A., Strek, G. and Beaulieu, N. 2001. Erosion Risk Mapping; a Methodological Case Study in the Colombian Eastern Plains. *J. Soil Water Conserv*., **57(3)**: (http://www.swcs.org/t_pubs_journal_MayJune02_erosion.htm#Top)
13. Zengxiang, Z., Xulong, P., Xiaofeng, C. and Jiyuan, L., 1996. Mountain Soil Erosion Mapping in Central Tibet using Remote Sensing and GIS, In: *Proceedings of 4th International Symposium on High Mountain Remote Sensing Cartography,* August 19-29, 1996.

روش نیمه تفصیلی تهیه نقشه فرسایش خاک بر اساس کاربرد BLM و تصاویر ماهواره‌ای

س. ح. ر. صادقی

چکیده

جمعیت در حال رشد به انرژی و غذای بیشتری احتیاج داشته که بایستی از طریق منابع محدود موجود تأمین شود. از آنجایی که قابلیت ذاتی منابع به طور صحیح ارزیابی نمی شود، مشکلات زیادی از قبیل سیل و خشکسالی و در اندازه های بزرگ در سرتاسر جهان رخ می دهد. فرسایش خاک به عنوان یکی از مهمترین اشکال تخریب اراضی مشکلات جدی برای نسل آینده و حتی نسل فعلی ایجاد می نماید. بنابر این ارزیابی بزرگی و توزیع مکانی انواع مهم فرسایش خاک یعنی سطحی، شیاری و آبکندی در کشورهای در حال توسعه به واسطهٔ نیاز به مبانی توسعه ای بیشتر کاملا" ضروری است. در تحقیق حاضر تلاشی در راستای معرفی یک روش بعمل آمده که از طریق آن، شرایط فعلی وضعیت فرسایش خاک تعریف و به صورت نقشه ارائه می گردد. در روش پیشنهادی، اطلاعات موجود و با دقت قابل قبول از قبیل حساسیت تشکیلات زمین شناسی به فرسایش، نقشه های تیپ اراضی و شیب برای تعیین مناطق نسبتا" همگن و از طریق رویهمگذاری نیاز می باشد. سپس اشکال فعلی فرسایش خاک از طریق پر کردن فرمهای اصلاح شده روش مدیریت ا راضی ایالات متحده (USBLM) در صحرا و طبقه بندی نهایی هر نوع از فرسایشها بر اساس مجموع امتیازات بدست آمده، ارزیابی و وضعیت کلی واحد مطالعاتی نیز به صورت یک رابطهٔ کسری نشان داده می‌شود. دیدگاه پیشنهادی برای بیش از شش میلیون هکتار از سطح آبخیزهای کشور اجرا شده و موئد توانمندی آن در انعکاس عوامل مؤثر بر فرسایش، برای مدیریت منابع طبیعی و دستیابی به توسعهٔ پایدار بوده است. برای ارائهٔ دقیق روش کار، مطالعات انجام شده در حوزهٔ آبخیز برهموم در استان مرکزی به مساحت۴۲۳۶/۲ هکتار در این تحقیق عرضه گردیده است. روش پیشنهادی برای بسیاری از مناطق واجد اطلاعات پایه و اساسی و با حداقل داده‌ها و اطلاعات کاربرد دارد.