Vulnerability of soils in the watershed of Wadi El Hammam to water erosion (Algeria)

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Abstract
Located in the north west of Algeria, the watershed of Wadi El Hammam is threatened by water erosion that has resulted the silting of reservoirs at cascade: Ouizert, Bouhanifia and Fergoug. The objective of this study is to develop a methodology using remote sensing and geographical information systems (GIS) to map the zones presenting sensibility of water erosion in this watershed. It aims to produce a sensibility map that can be used as a reference document for planners. The methodology presented consists of three factors that control erosion: the slope, the friability material and the land use, which were integrated into a GIS. The derived erosion sensibility map shows three areas of vulnerability to water erosion: low, medium and high. The area of high vulnerability corresponds to sub-basin of Fergoug.

Key words: GIS, remote sensing, Wadi El Hammam, water erosion, watershed

INTRODUCTION
The erosion of soil by rain and runoff is a phenomenon widely distributed in the different countries [BANASIK et al. 2001, 2012; BAK, DABKOWSKI 2013; PANAGOS ET al. 2015; WALLING, WEBB 1996]. In Algeria, about 6 million hectares are exposed to active erosion, an average of 120 million tons of sediment are washed away each year [HEDDAJ 1997]. The slopes of Algerian Northwest which represent a great potential for agricultural production are affected for a century by a degradation of vegetable cover and land dynamics [MORESI et al. 2004]. The annual losses of capacity of storage of water in dams are estimated about 20 million m³ and are due to siltation [REMINI, HALLOUCHE 2005].

Remote sensing and geographic information system (GIS) are increasingly used for the study of surface phenomena and form tools essential in interactive decision support systems operational for risk management operations [BOUKHEIR et al. 2006]. The implementation of effective measures for the conservation of soil must be preceded by an assessment of the erosion risk in the space [MOUSSA et al. 2002; SOUCHERE et al. 2005].

This study focuses on mapping the sensitivity to erosion of the basin side of the Wadi El Hammam, located in the North West of Algeria and controlling three dams in cascade Ouizert, Bouhanifia and Fergoug. Recent silting measures carried out by the national agency of dams and transfers (ANBT) reveals a low rate observed in the Ouizert and Bouhanifia dams (4%, 6%), a very high rate in the Fergoug dam (95%).

In this work, we propose a mapping methodology for areas vulnerable to erosion that the source of solid materials extracted and transported by water based on
field, remote sensing and topographic data. Developed GIS allowed us to overlay and analyze several factors such as slope, the nature of the exposed materials and vegetation. The sensitivity to erosion deducted map allows detecting producing areas of sediments, with the aim of erosion control planning for the preservation of the three dams and the irrigation downstream.

STUDY AREA

Watershed Wadi El Hammam is located in North West part of Algeria and is part of the great basin of the Macta. It includes three sub-basins: Ouizert, Bouhanifia and Fergoug (Fig. 1). At the Fergoug dam, Wadi El Hammam has a watershed of 8251 km², corresponding to the strongest reliefs and downstream Bouhanifia part and constitutes the own dam impluvium: these are the mountains of Benichougrane which dominates 850 m Mohammadia plain. The largest portion of the watershed feeds Bouhanifia dam and extends on attenuated the Oran Meseta in an area of reliefs where yet, energetic erosion dug deep valleys framed by witnesses who dominate the bottom of 200 to 300 m [BENCHETRIT1972].

The climate of the region is semi-arid Mediterranean, with an average annual rainfall of about 260 mm (average for the period 1995–2010), poorly distributed along the year. The rainy season lasts from September to April. Over the period 1930–2002, the annual precipitation has decreased by about 26% on average [MEDDI et al. 2009]. The lithology of the watershed reflects a great diversity of surface formations with predominance of clay soils derived from marl formations [BOUCHETATA et al. 2006]. Grain and vegetable crops dominate the southern part of the basin. These cultures cover the soil seasonally and leave it the rest of the year. To the North, forest cover deteriorated by the anthropogenic action and recent fire, occupies the steep slopes of the watershed of Wadi Fergoug. It should be noted that subsistence agriculture prevails with over exploitation of soils, a permanent clearing and intensive overgrazing. Faced with this situation, the erosion found its scope of development due to the lack of protective vegetation, low resistance of the land and their slopes.

MATERIALS AND METHODS

The methodology used in this study is based on satellite data, topographic, lithological and of ground observations. These data are then integrated and analyzed in a GIS environment for restitution and mapping of areas prone to water erosion (Fig. 2). The input data cover:
- a slope map,
- a lithologic map digitalized and georeferenced,
- a land cover map digitalized and georeferenced.

Map of land use

The classification is led by the method of maximum likelihood. It is based on direct observation of the categories of land use allowed obtaining a map of land tenure. Eleven classes of vegetation cover appear. Each class has been assigned a degree of protection against water erosion (Tab. 1):
Level 1: not protective,
Level 2: little protective,
Level 3: moderately protective,
Level 4: highly protective.
**Table 1. Sensitivity classes of vegetation**

| Vegetation cover          | Degree of protection |
|---------------------------|----------------------|
| Bare soils                | 1                    |
| Highly degraded path      | 2                    |
| Rangelands                |                      |
| Cropland                  | 2                    |
| Semi-intensive farming    | 3                    |
| Cereals                   | 3                    |
| Extensive agriculture     |                      |
| Trees Clear Matorral: facies *Tetraclinis articulata* and *Oleo lentiscus* | 4 |
| Dense wooded Matorral: facies *Tetraclinis articulata* | 4 |
| Trees Clear Matorral: facies *Tetraclinis articulata* and *Quercus ilex* | 4 |
| Vine                      |                      |

Source: elaborated acc. to BOUCHETATA et al. [2006].

The classification of ROOSE [1977] has served us to identify an appropriate classification. Roose classified plant canopies into three groups:
- permanent cover,
- temporary vegetation cover,
- incomplete vegetation cover.

This mode of classification was detailed by subdividing the plant covered group incomplete in two groups: grazing and bare floors

a) The permanent cover includes:
- Canopy:
  - Trees Clear Matorral: facies *Tetraclinis articulata* and *Oleo lentiscus*
  - Dense wooded Matorral: facies *Tetraclinis articulata*

Trees Clear Matorral: facies *Tetraclinis articulata* and *Quercus ilex*
- Forest reforestation
- Perennial crops:
  - Wine plantation and orcharding
b) The temporary canopy includes:
- Annual crops
  - Cereals, extensive agriculture and semi intensive and cropland.
c) The incomplete vegetation cover includes:
- Pasture concern much degraded and the less degraded rangeland
- Bare floors: it’s completely bare and uncultivated soils

The plants cover classification and the allocated degree of protection against erosion allowed the development of a new map of land use.

**Map of slopes**

The digital terrain model DTM (with a resolution of 30 m by shuttle radar topography mission SRTM) was used to produce the map of slopes. It was subdivided into four classes: 0–5%; 5–15%; 15–25% and upper to 25%. Each class is assigned an index ranging between 1 and 4 (Tab. 2), 1 assigned to the low slopes (<5%), 4 to the steep slopes (>15%).

**Table 2. Classes of slope and assigned index**

| Slope, % | Index assigned |
|----------|----------------|
| 0–5      | 1              |
| 5–15     | 2              |
| 15–25    | 3              |
| >25      | 4              |

Source: own study.

**Map of friability**

Lithologic map of the Wadi El Hammam watershed reveals a great diversity of surface formations with predominance of clay soils derived from marl formations. For each type of soil, sensitivity classes are assigned from our field knowledge, describing the nature of rocks on the geological map, and their sensitivity to smearing and cracking. One can thus distinguish four classes of materials (Tab. 3): resistant,
moderately resistant, vulnerable, and very vulnerable. Each class is assigned an index ranging from 1 and 4. Index 1 is assigned to material exposed to erosion and index 4 assigned for less erosion-proned materials.

RESULTS

The methodology developed in this study uses qualitative rules, assessments, and a hierarchy of parameters involved in water erosion: occupation of land (Fig. 3), friability of the material (Fig. 4) and degree of slope (Fig. 5). All of these data are integrated in a GIS for a better management of information. The combination of these maps following the rule of decision mentioned on Table 4, has allowed producing a thematic map called map of fragile lands (Fig. 6). It includes four classes: very fragile (0.33%), fragile (35.43%), moderately fragile (58.90%) and little fragile (5.34%), very fragile and fragile lands represent 35.76% of the watershed area.

Fig. 3. Land cover map; source: own elaboration

Fig. 4. Material friability map; source: own elaboration
The map of sensitivity to erosion (Fig. 7) has been developed by the interaction between the fragility of land and the degree of slope; using the rule of decision in Table 5. Three classes are bounded: low (65.18%), medium (26.18%) and high (8.64%).

The thematic maps of fragile land and sensitivity to erosion show that moderately fragile land areas have low sensitivity to erosion and occupy 65.18% of the study area. These areas are scattered throughout the region, mainly on land with a low slope to medium (<15%) covered of culture and matorral. Sensitivity medium to high affect Ouizert and Bouhanifa sub basin with a predominance for the Fergoug sub-basin, where we meet Marly terrain steep (>15%) and a cover nearly absent.

Table 4. Rules of decision for land fragility

| Occupation of lands | Very vulnerable | Vulnerable | Moderately vulnerable | Resistant |
|---------------------|----------------|------------|-----------------------|-----------|
| Not protective      | very fragile   | very fragile| very fragile           | fragile   |
| Little protective   | very fragile   | very fragile| moderately fragile     | moderately fragile |
| Moderately protective | fragile     | moderately fragile | little fragile | little fragile |
| Highly protective   | moderately fragile | little fragile | little fragile | little fragile |

Source: own study.
Table 5. Rules of decision for sensitivity to erosion

| Slope, % | Sensitivity to erosion depending on fragility of land |
|---------|-----------------------------------------------------|
| 0–5     | medium    | low       | low       | little      |
| 5–15    | high      | high      | medium    | low        |
| 15–25   | high      | high      | high      | medium     |
| >25     | high      | high      | high      | high       |

Source: own study.

DISCUSSION

The dominant classes of the sensitivity to erosion correspond to low and middle levels. These affect 91% of the study field. These areas correspond to areas of low to medium slopes, which also represent 69.68% of the total area of the watershed of Wadi El Hammam. This result shows that the sensitivity to erosion of the study area is mainly controlled by the degree of slope and the vegetable cover density.

The fragility of the erosion is triggered by human action caused agricultural practices on steep terrain. This is the case of the Sub basin of Fergoug where the slopes greater than 25% represent 35.31% of the surface of the Sub basin and 61.53% for those greater than 12.5% [BOUCHETATA et al. 2006]; these areas mainly marl and clay intended for pastures and intensive food crops, helps produce fragile lands to very fragile and therefore a strong sensitivity to erosion.

CONCLUSION

Items in topographic, lithological and land use maps were crossed in a geographic information system. Analysis and spatial modelling of the fragility of the lithological substratum, of cover plant and the degree of slope permitted to have a clear idea about the management basin watershed of Wadi El Hammam and therefore produce a project more in harmony with the need to protect the dams, located downstream, against siltation.

In this catchment, the low to moderate slopes dominate South, South West and central, from the Ouizert sub-basin to the boundary of Bouhanifia. These areas represent 69.68% of surface, the rest, which is 30.32% of area is reserved for the steep slopes scattered in various parts and highly concentrated at the sub basin of Fergoug.

The mapping areas to water erosion in the watershed of Wadi El Hammam has made it possible to distinguish three sensitivity classes. Interested in the low class to average 91.36% of the total area. These levels of sensitivity are due to the low to medium slopes above the basin studied and are relevant to the Ouizert and Bouhanifia sub-basin. The class of highly erodible soils also affects these two sub-basins and especially the sub watershed Fergoug.

To avoid repeating the scenario of Fergoug dam, the Ouizert and Bouhanifia dams currently having a low sedimentation rate, would be condemned to siltation in the medium to long term if we do not make an adjustment of risk areas erosion by the prohibition of agricultural practices on steep slopes, the forest protection, reforestation of denuded areas, installation of retaining walls and terracing that preserve land for agriculture. Map of sensitivity to erosion resulting from this work, draft that it be improved by extensive research on soil erodibility, and the rainfall erosivity, allows policymakers to better target their preventive intervention strategies to reduce siltation of dams downstream.
REFERENCES

BAK L., DĄBROWSKI SZ.L. 2013. Spatial distribution of sediments in Suchedniow reservoir. Journal of Water and Land Development. No. 19 p. 13–22.

BANASIK K., GÓRSKI D., MITCHELL J.K. 2001. Rainfall erosivity for East and Central Poland. In: Soil Erosion Research for the 21st Century. Proceedings of International Symposium, 3–5 January 2001, Honolulu. Ed. J.C. Ascough, D.C. Flanagan. St Joseph, Michigan. ASAE p. 279–282.

BANASIK K., GÓRSKI D., POPEK Z., HEJDUK L. 2012. Estimating the annual sediment yield of a small agricultural catchment in central Poland. In: Erosion and sediment yields in the changing environment. Proceedings of the Chengdu Symposium. Oct. 2012. IAHS Publ. 356 p. 267–275.

BENNETT M. 1972. L’érosion actuelle et ses conséquences sur l’aménagement de l’Algérie. Paris. PUF p. 216.

BOUCHETATA A., BOUCHETATA T. 2006. Propositions d’aménagement du sous bassin versant de Fergoug (Algérie) fragilisé par des épisodes de sécheresse et soumis à l’érosion hydrique. Sécheresse. Vol. 17. No. 3 p. 415–424.

BOUKHEIR R., CERDAN O., ABDALLAH C. 2006. Regional soil erosion risk mapping in Lebanon. Geomorphology. Vol. 82 p. 347–359.

DEMMAK A. 1982. Contribution à l’étude de l’érosion et des transports solides en Algérie. Thèse de docteur ingénieur. Paris. Université Pierre et Marie Curie. pp. 323.

GLIZ M., REMINI B. 2011. Impact of the irrigation with des eaux chargées en matières en suspension sur la perméabilité du sol (cas de la plaine de l’Habra). Communication. Colloque international sur l’eau et développement. No. 19 p. 13–22.

GOMER D. 1992. Ecoulement et érosion dans des bassins versants à sols marneux sous climat semi-aride méditerranéen. Eschborn (Allemagne). GTZ-ANRH pp. 207.

HEDDAJ D. 1997. La lutte contre l’érosion en Algérie. Bulletin Réseau Erosion. No. 18 p. 168–175.

KOUTI A. 1985. Approche de la dynamique actuelle dans un bassin versant du tell oranais: cas du bassin d’Oued Fergoug (Benichougrane). Thèse de doctorat 3ème cycle. Université de Paris 7: Géographie pp. 150.

MEDDI M., MORSI B. 2001. Étude de l’érosion et du ruissellement sur bassins-versants expérimentaux dans les Monts de Benichougrane (Ouest d’Algérie). Zeitschrift für Gemorphologie. NF. Allemagne. No. 45 p. 443–452.

MEDDI M., TALIA A., MARTIN C. 2009. Evolution récente des conditions climatiques et des écoulements sur le bassin versant de la Macta (nord ouest de l’Algérie).

Article scientifique. Géographie physique et environnement. Vol. 3 p. 61–84.

MEKERTA B., SEMCHA A., BENDAoud M., TROALEN J.P. 2007. Caractérisation et répartition spatiale des propriétés géotechniques des sédiments d’envasement de la retenue du barrage du Fergoug. Colloque International sur les Sols et Matériaux à Problèmes (SOMAPRO). Du 9–11 mars, Tunis p. 79–86.

MORSI B., MAZOUR M., MEDEDEJ N., HAMOUDI A., ROOSE E. 2004. Influence de l’utilisation des terres sur le risque du ruissellement et d’érosion sur les versants semi-arides du nord-ouest de l’Algérie. Note de recherche. Sécheresse. Vol. 15. No. 1 p. 96–104.

MOUSSA R., VOLTZ M., ANDRIEUX P. 2002. Effects of the spatial organization of agricultural management on the hydrological behavior of a farmed catchment during floods events. Hydrological Processes. Vol. 16 p. 393–412.

OLIVRY J.C. 1991. Cours d’initiation à l’étude et la mesure de l’érosion et des transports solides. Cahiers ORSTOM, Série Pédologie. Vol. 25 pp. 110.

PANAGOS P., BABBALO C., BORELLI P., MEUSBURGER K., KLIX A., ROUSEVA S., TADIC M.P., MICHAELIDES S., HRABALIKOVA M., OLSEN P., AALTO J., LAKATOS M., RYMSZEWICZ A., DUMITRESCU A., BEGUERIA S., ALEWELL C. 2015. Rainfall erosivity in Europe. Science of the Total Environment. Vol. 511 p. 801–814.

REMINI B. 2000. L’envasement des barrages. Bulletin Réseau Erosion. No. 20 p. 71–165.

REMINI B., HALLOUCHE W. 2005. Prévision de l’envasement dans les barrages du Maghreb. Lethys Journal. No. 4 p. 69–80.

ROOSE E. 1977. Erosion et ruissellement en Afrique de l’Ouest: vingt années de mesures en petites parcelles expérimentales. Paris. ORSTOM. Travaux et documents de l’ORSTOM. No. 78 pp. 108.

TOUCHE A., CERDAN O., DUBREUIL N., LE BISSONNAIS Y., KING C. 2005. Modeling the impact of agro-environmental scenarios on Overland flow in a cultivated catchment (Normandy, France). Catena. Vol. 61 p. 229–240.

TRIBAK A., EL GAOUIANI A., ABAHROUR M. 2009. Evaluation quantitative de l’érosion hydrique sur les terrains marneux du Pré-Rif oriental (Moroc): cas du sous bassin de l’oued Tlata. Sécheresse. Vol. 20. No. 4 p. 333–337.

UNESCO 1986. Problèmes d’érosion, transport solide et sédimentation dans les bassins versants. Project 5.3 of the International Hydrological Program. Prepared under the presidency of A. Saudbarg, director of the publication WR White pp. 161.

WALLING D.E., WEBB B.W. 1996. Erosion and sediment yield: a global overview. In: Erosion and sediment yield: Global and regional perspectives. Proceedings of the Exeter Symposium. July 1996. IAHS Publ. 236 p. 3–19.

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Podatność gleb w zlewni Wadi El Hammam na erozję wodną (Algieria)

STRESZCZENIE

Słowa kluczowe: erozja wodna, GIS, metodologia teledetekcji, Wadi El Hammam, zamulanie zbiorników, zlewnia rzeczna

Położona w północno-zachodniej Algierii zlewnia rzeki Wadi El Hammam charakteryzuje się dużą podatnością na procesy erozji wodnej, które prowadzą do zamulenia zbiorników w kaskadzie: Ouizert, Bouhanifia i Feroug. Celem badań było opracowanie metodologii wyznaczania stref w zlewni o różnej podatności na erozję z wykorzystaniem teledetekcji i geograficznych systemów informacyjnych (GIS) oraz stworzenie mapy wrażliwości gleb na erozję, która może być wykorzystana jako dokument referencyjny dla planistów. Przedstawiona metodyka polega na integracji w GIS trzech czynników warunkujących procesy erozji, tj.: nachylenia stoków, struktury gleb i użytkowania terenu. Na opracowanej mapie wyróżniono trzy klasy charakteryzujące: małą, średnią i dużą podatność zlewni na procesy erozji wodnej. Dużą podatność na erozję wykazują głównie obszary na terenie zlewni zbiornika Feroug.