# EFFECT OF DIFFERENT LAND USE TYPES AND THEIR IMPLICATIONS ON LAND DEGRADATION: THE CASE OF THE WATERSHED ISSER-TLEMCEN (ALGERIA)

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*Abstract*

This work focuses on water erosion observed in the northwest region of Algeria. It deals with the specific case of cereals, whose surface status (SS) influences strongly the formation of runoff during the rainy season, due to the formation of slaking crusts. The objective of this work is to study the surface states under different modes of land use, practiced in the region in order to apprehend the contributing areas of runoff and land loss. For this, surface observations were carried out taking into account the spatial organization of SS created by the soil tillage. The surveys are completed at the watershed of the Isser, at a scale of $m^2$, on six plots sample submitted different cropping systems. These observations were completed by in situ measurements of soil infiltrability. It shows that runoff is closely related to the hydrous and structural state of soil. It decreases from upstream to downstream slopes and is higher on the south-facing slopes than the north-facing ones.

***Keywords:*** Isser, erosion, land use, surface status, runoff.

## 1. Introduction

In northern Algeria, the phenomenon of water erosion is the *most important form* of *physical soil degradation* affecting the reliefs, the soil production and the slopes stability. It results from the combination of several factors: rainfall aggressiveness; soil erodibility; dissection of the relief; low vegetal cover, etc. This phenomenon doesn't helps only to reduce soil productivity, but also to the pollution of surface water and premature siltation of hydraulic infrastructure.

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In Algeria, mountain regions have a significant socio-economic issue (agriculture, forest, patrimony...). They are very vulnerable to the phenomenon of water erosion. The relation between vegetation, soil and water is largely disturbed there (Benchetrit, 1972). The population's subsistence is increasingly threatened by soil loss.

The study of the runoff and erosion risks on a watershed requires a good understanding of the hydrological behavior of the soil and, in particular, the infiltration capacity that depends on its surface conditions and soil types (Coutadeur et al., 2002). In this context, the present work consists in studying the surface states in the marl slopes of the Oued Isser in the Algerian northwest in order to simulate the hydrological behavior of soils against water erosion. It aims at determining the effects of various land uses on the dynamic of soil surface states transformation.

In fact, runoff and infiltration are highly correlated to rain at the beginning of the downpour. Later, it is the surface states that largely determine runoff and consequently soil loss. The closed surfaces will produce rapidly the free water on the soil surface. For the free water to stream, it must also avoid the trap of opened surfaces, i.e., highly permeable stonechat zones, deep cracks, galleries of termites and earthworms. Moreover, the cover of soil by dead or alive plants, delays the onset of slaking crusts by intercepting the water drops, it reduces their kinetic energy and thus their degrading power. In the same way, crop residues create a permanent roughness which dam the runoff spread and favors the infiltration of water into the ground (Gascuel-Odoux et Heddadj, 2000). The livestock trampling and the overgrazing modify the soil surface conditions (pore closure, settlement, etc.), reduce the infiltration of water into the soil and make it easier the runoff (Mazour, 2004). Some authors have established power functions between the slopes gradient and sheet erosion (Govers, 1991; McCool *et al.*, 1993). It has been shown, based on simulated rain that more the slope is strong, the weaker infiltration is because of the change of the soil surface properties and the introduction of the slaking crust which is shown by the increase of erosion (Poesen, 1984). J. Dumas (1965) demonstrated that there is a relation between the analytical characteristics of soil and erodibility and especially lingered over the influence of stones on the erodibility coefficient.

The knowledge of the intensity of surface runoff in the agricultural plots is difficult to acquire. Such knowledge requires heavy experimental devices which often require a time presence in the ground. We present here the point-quadrat method which is a simple and low cost method suggested by E.B. Levy and E.A. Madden (1933). This runoff indicator method was adopted by many authors (Boudet, 1984; Daget et Poissonnet, 1971, 1991; Daget et al., 1995; Gaston, 1992; PNUD, 2006; Boughalem, 2013). An example will be described in a marly slope of the Isser on brown clay calcareous soils. Surveys are conducted at a scale of $m^2$, on a sample of six plots under different cropping systems.

## 2. Study area

The watershed of Isser is located in the north west of Algeria (Fig. 1), between longitude 1 ° 20 '31 "W and 0 ° 52' 28" W and latitude 34 ° 41 '22 "N and 35 ° 9' 37 'N. It covers an area of 1122 km² for a perimeter of 207.7 km).

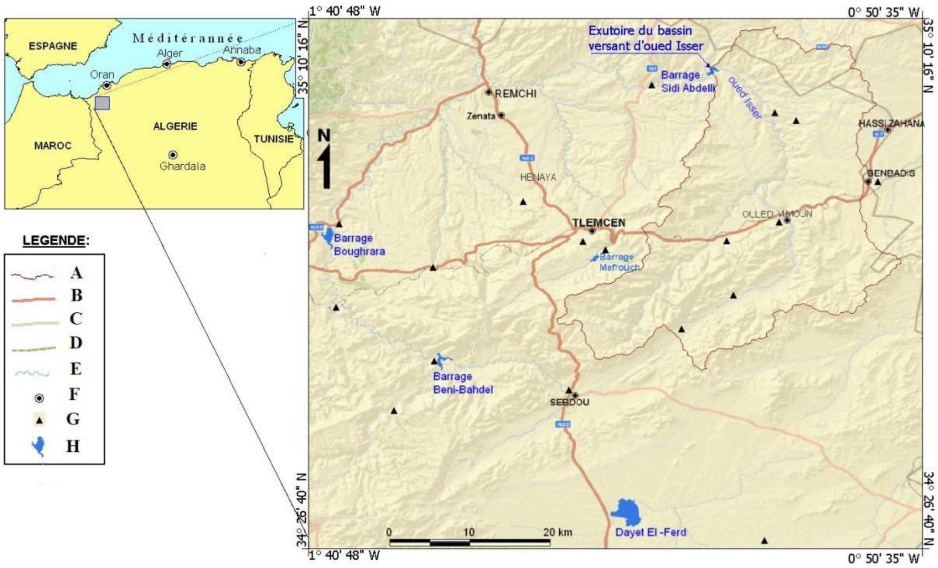


*Fig. 1.* Location of the study area – A: Watershed limit; B: Major road; C: Arterial road; D: County boundary; E: Watercourse; F: Community; G: Station rainfall; H: Water Plan

Right bank affluent of the Tafna River, the Oued Isser is 81 km long. It rises in Ain Isser located in the south of Ouled Mimoun. It is characterized by:

- a Mediterranean semi-arid climate, with annual rainfall ranging from 280 mm to 500 mm; These rains are characterized by a spatio-temporal irregularity and a short duration regime and high intensity (the maximum intensity can reach 84 mm / h in 30 min);
- a very steep and highly dissected relief, often with steep slopes and a dense drainage network;
- a lithology defined by rocks mostly soft (marl and tender sandstones) which predisposes these areas to different processes of erosion;

very degraded vegetation, characterized by weak densities of recovery and bad regeneration conditions.

The northern area of the basin is designed to cereal (including wheat and barley). Some forests (Zerdeb and Fougahal) still exists on the jurassic rocky mass. In addition, the area occupied by degraded or dead forest cover is 39% of the total basin area.

## 3. Materials and methods

The study of soil surface conditions is based on an experimental system that we installed in the north of the basin on three crop years (2008-2010) which is composed of six rectangular farming parcels of 200 $m^2$ each, on slopes starting from 15% and 20 (Fig. 2).

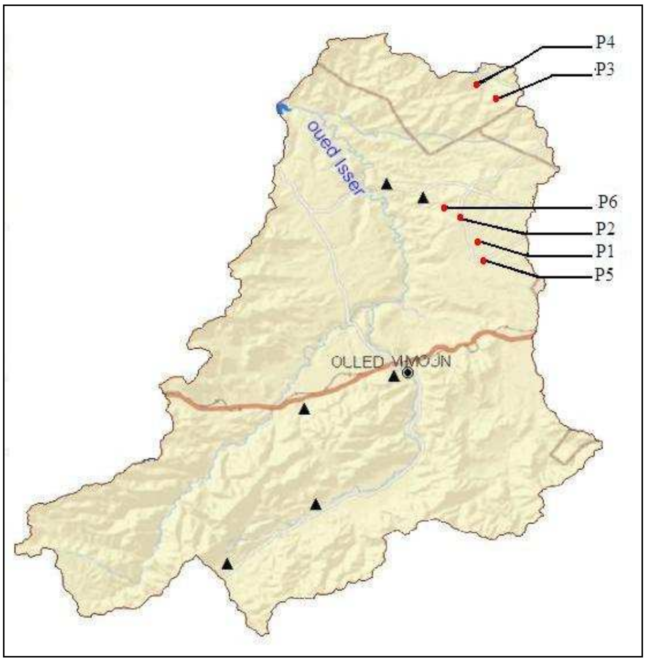


*Fig. 2.* Location of experimental plots through the watershed of Isser

Two of these plots (P1 and P2) were sown barley, without ploughing (direct seeding), the four other plots (P3, P4, P5 and P6) were sown wheat after ploughing. The experimental plots were also selected in order to have 2 exposure states (north and south). For each of these states, we chose a plot at the top of the slope and another down the slope to enlarge the spectrum of variations. The choice of the test plots was first controlled by the technical requirements such as the accessibility and the availability of water then, the uniformity of the soil surface, soil type, the possibility of guarding and especially the consent of the landowner. Table1 summarizes the characteristics of the studied plots.

*Tableau 1*

**Studied plots characteristics**

| Plot | Seeding | Exposure | State on the slope | Talling |
|---|---|---|---|---|
| P1 | Barley | North | Down the slope | Direct seeding |
| P2 | Barley | North | Top of the slope | Direct seeding |
| P3 | Soft weet | South | Down the slope | Tillage |
| P4 | Soft weet | South | Top of the slope | Tillage |
| P5 | Soft weet | North | Down the slope | Tillage |
| P6 | Soft weet | North | Top of the slope | Tillage |

The work equipment includes, in addition to plots, two wooden frames (see Fig. 3) and a straight and point knitting needle. The first frame is 1m$^2$, with a grid that comprises 100 grills of 10 cm$^2$. The observations are made on 110 intersection points. Thus, the data are provided directly in %. The second frame is a support. It is used for holding the first one horizontal to the plot without touching the vegetal cover. If the height of the first frame is smaller than that of the vegetation, it will crush and sprawl over an area larger than reality.

*Fig. 3.* Point-quadrat method (left: surface states in August 2009, right: surface states in February 2009)

The surveys of surface states were carried out four times a year: autumn (November), winter (February), spring (end of April) and summer (August). The choice of these dates was made according to a preliminary study on the variation of the hydrous state, the soil condition (tilled or not, covered or not ...) and the rainfall distribution over the year (Morsli, 1997; Boughalem, 2007). The method consists in describing the surface conditions of experimental plots by placing the wooden frame fitted with a grid, at 5 cm height from soil, and by letting (systematically) a knitting needle go down to the intersection points corresponding to the measurement framework.

At the point of impact with the ground, we counted the following points:

- the percentage (%) of the covered surface leveled with the ground (CS% = weed + litter + stones);

- the percentage (%) of opened surfaces (OS% = aggregates + cracks + wildlife holes)
- or closed (CS% = film, crusts, packed areas and pebbles included in the soil mass) (Roose, 1996).

Therefore we notice the absence or presence of each element. Thus, the data are provided directly in %. The sum of covered and bare surfaces is equal to 100%. In the same way, the sum of the opened and closed surfaces is equal to 100 %. Five surveys were made on each plot along a transect in order to estimate the variability within plots. In fact, it is a quick method which is adaptable to all situations and does not require a high technicality. However, it has many disadvantages. It is based on chance because only the components actually affected by the needle are taken into consideration. In addition, the repeated passage of observers on the experimental plots favors the differential compaction of the soil by the trampling and it disrupts the runoff and erosion on the portion of the observed surface. The observations of surface states are, as we noted above, coupled with "in situ" measurements of soil infiltrability by the monocylinder method suggested by E. Roose and al. (1993).

In order to have comparable results, all measurements were performed in the summer period during August, when soils were in their driest condition (soil moistness = 5%). However, the initial soil hydrous conditions varies during the year, that's why repetitions were conducted in autumn (November) and winter (February) and spring (the end of April) on soils that contained respectively a content of water measured by weight percent with rates 15%, 45% and 28% in the first ten centimeters of soil.

## 4. Results

The spatial and temporal variability of the infiltration of water into the ground is described by infiltration curves, representing the vertical distribution of water content in the ground, at different given times (Fig. 4). All these curves have the same rate of decrease over time.

### *The influence of the initial water status of the soil on the water infiltration*

During the three crop years, the infiltration rates recorded in summer (August) are 2-3 times higher than those observed during the wet season in February (Fig. 4). They range from 998 to 344 mm / h for dry soils (moisture = 5%), from 620 to 50 mm / h for wet soils (humidity = 15-28%) and from 398 to 38 mm of rain per hour for very wet soils (moisture = 45%). These values show that the infiltrability of the soil depends mainly on his initial water status.

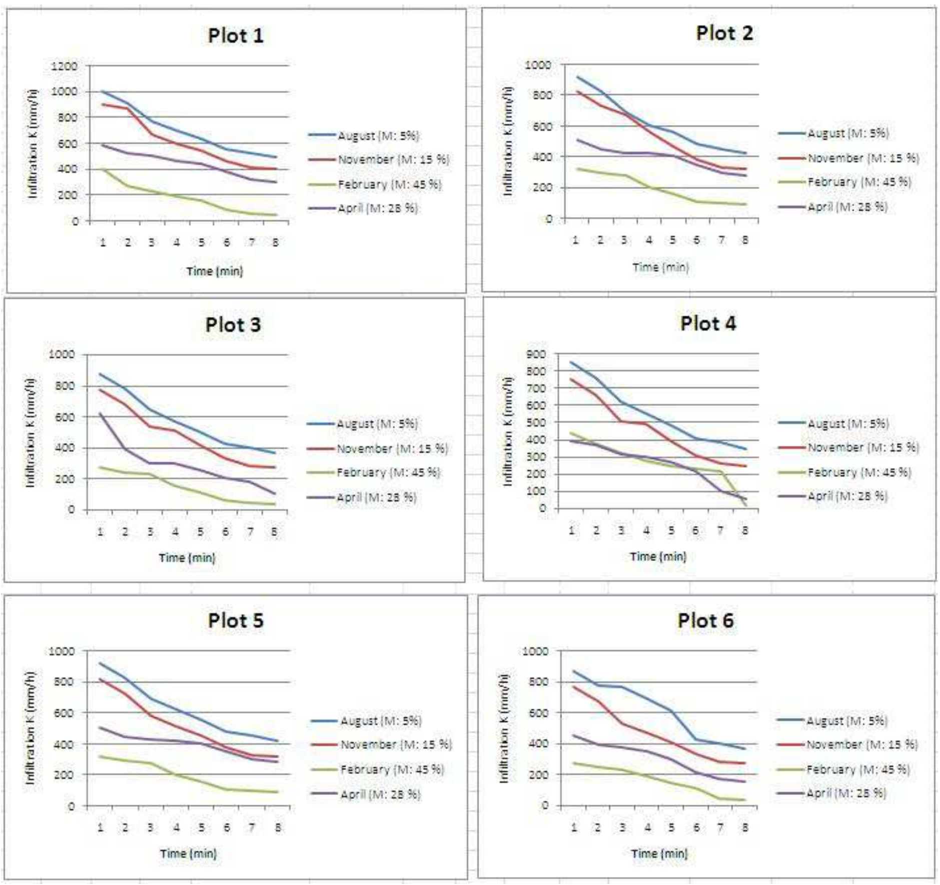


*Fig. 4.* Infiltration curves of the studied plots

### *The study of surface conditions under different modes of land use*

The results show that the components of the soil surface status of each plot evolve from a survey to another. The most dynamic components are the vegetation cover and the soil which vary inversely (Table. 2).

Tableau 2

**Characteristics of the surface states of the studied plots**

| | Plots | Surface states | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Stones (%) | Litter (%) | Weed (%) | Covered surface (%) | Bare surface (%) | opened surface (%) | Closed surface (%) |
| August | P1 | 10 | 23 | 4 | 37 | 63 | 64 | 36 |
| | P2 | 9 | 13 | 7 | 29 | 71 | 67 | 33 |
| | P3 | 7 | 10 | 3 | 20 | 80 | 49 | 51 |
| | P4 | 9 | 9 | 2 | 19 | 81 | 50 | 50 |
| | P5 | 8 | 10 | 10 | 28 | 72 | 67 | 33 |
| | P6 | 9 | 7 | 6 | 22 | 78 | 64 | 36 |
| | | | | | | | | |
| November | P1 | 10 | 20 | 4 | 34 | 66 | 34 | 66 |
| | P2 | 8 | 14 | 7 | 29 | 71 | 56 | 44 |
| | P3 | 7 | 3 | 8 | 18 | 82 | 30 | 70 |
| | P4 | 9 | 4 | 2 | 15 | 85 | 55 | 94 |
| | P5 | 9 | 7 | 12 | 28 | 72 | 56 | 44 |
| | P6 | 9 | 4 | 5 | 18 | 82 | 33 | 67 |
| | | | | | | | | |
| February | P1 | 9 | 23 | 24 | 56 | 44 | 17 | 83 |
| | P2 | 10 | 18 | 22 | 50 | 50 | 6 | 94 |
| | P3 | 7 | 15 | 19 | 41 | 59 | 8 | 91 |
| | P4 | 9 | 14 | 14 | 37 | 63 | 5 | 91 |
| | P5 | 8 | 20 | 21 | 49 | 51 | 6 | 94 |
| | P6 | 9 | 13 | 18 | 40 | 60 | 7 | 93 |
| | | | | | | | | |
| April | P1 | 10 | 26 | 57 | 93 | 7 | 42 | 58 |
| | P2 | 9 | 25 | 56 | 90 | 10 | 43 | 57 |
| | P3 | 7 | 23 | 58 | 88 | 12 | 12 | 88 |
| | P4 | 9 | 20 | 56 | 85 | 15 | 27 | 73 |
| | P5 | 8 | 24 | 58 | 90 | 10 | 44 | 56 |
| | P6 | 9 | 21 | 58 | 88 | 12 | 36 | 64 |

During the summer (August), the marl soils have the biggest proportion of opened areas (50-57%). In winter (February), the weakest proportion (0%), with intermediate values in autum and spring (10-47%). This is due to the phenomenon of shrinkage and swelling characteristic of the marly area.

### *Plowed plots*

The plowed plots (P3, P4, P5 and P6) have a proportion of covered area of (15-90%) less important than the plots in direct seedling (29-93%). The weakest proportion in covered area was recorded during the first survey (August). This rate increases gradually to reach very high values (90%) during the fourth survey (April). Plots P5 and P6 north-facing have a proportion of covered area of (18-90%) more important than plots P3 and P4, south-facing (15-88%). Moreover, the average infiltration varies according to the slope exposure "north/south" and increases from upstream to downstream slopes. It is higher on the P5 and P6 north-facing plots (871-38 mm/h) than the south-facing ones (P3 and P4: 850-37mm/h).

*North-facing plots (P5 and P6)*

The plot P6 north-facing and situated at the top of the slope has a proportion of covered area ranging from 18 to 88% and a modest average infiltration (403 mm/h). On the plot P5 north-facing and situated at the bottom of the slope, the infiltration reaches 449 mm/h and the coverage rate is higher (up to 90%).

*South-facing plots (P3 and P4)*

The proportion of covered area is moderate (15-85%) on the plot P3 situated at the bottom of the slope on which we recorded an average water infiltration ranging from 871to 82 mm/h. On the plot P4, situated at the top of slope, the proportion of covered area ranges from 18-88%. The average water infiltration at that level is even lower (852-50 mm/h). While it can reach 38 mm/h, when the soil is moist (3rd trial in February).

*No-tilled plots*

Under direct seeding, the plots P1 and P2 have the highest recovery rates (29-93%). The average infiltration is variable and increases from upstream to downstream slopes. That's why it is low on the P2 plot situated at the top of the slope (920-88 mm/h) while it reaches 988 mm/h on plot P1 at the bottom of the slope.

*Relations between infiltrability and soil characteristics*

The observed relations between the measured infiltrabilities and the soil characteristics are presented in Fig. 5. We notice that the observed infiltrabilities are well correlated with the soil opening (R2 = 0.76).

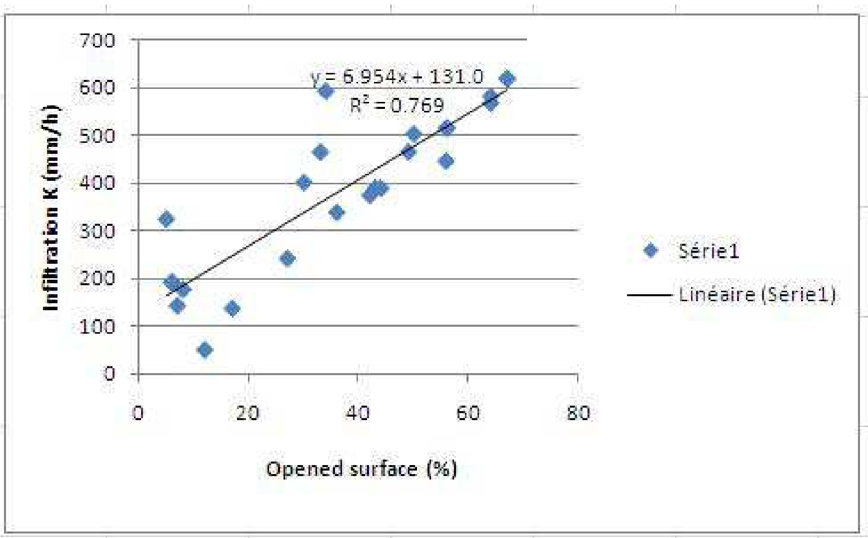


*Fig. 5.* Relation between infiltrability and the open ground surface

## 5. Discussion

The plowed plots (P3, P4, P5 and P6) are the most anthropic plots. The tillage loosens the soil and destroys the natural vegetation. It reduces the organic content of the superficial soil horizons, their structural stability and infiltration capacity. This explains the weak vegetation density (19-28%) in these four plots during the first survey (August). This rate increases gradually to reach very high values (90%) during the 4th survey. These plots do not benefit from a protection throughout the year. This seasonal variation in the rate of recovery leads to a seasonal variation of runoff and erosion, especially as the ploughing period coincides with the period of heavy rains.

The ploughing causes risks of gully on the plots located at the top of slopes (P4 and P6). As they are less consistent, they are more erodible. These changes in the surface states at the plowed plots have caused a change in the hydrological behavior of soils.

Under direct seeding (plots P1 and P2), we notice that the percentage of the bare ground has decreased significantly while the percentage of vegetal cover has gradually increased (from 1st to 4th survey). Moreover, these two plots benefit from the protection essentially guaranteed by the vegetal cover constant against the detachment of the particles due to the kinetic energy of raindrops. This means that the fractions of intercepted or amortized rain drops are very important. The average infiltration is high on the parcels sown directly

(998-44mm/h), while it is medium on the plowed plots and varies from 871 to 37 mm/h. The presence of a litter on the ground surface, strongly transformed by earthworms and termites, explains the disappearance of slaking crusts and the improvement of water infiltration capacity by direct seeding. Under direct seeding, the infiltration average is variable and increases from upstream to downstream slopes. That is why it is low on the P2 plot located at the top of the slope (920-88 mm/h) whereas it is 988 mm/h on the P1 plot situated at the bottom of the slope.

The results show that the direct seeding is an exception because it is a practice with the least degraded surface status, and that for the following reasons: i) surface observations did not reveal any changes in the surface over the study period; ii) we rarely observe the formation of sedimentary crusts, which is a witness of the runoff formation. We have found in general that under the same climatic conditions, the studied plots have different reactions due to the difference in their surface states. On the plot P4 (plowed, south facing and located at the top of slope), we have recorded an infiltration of 165 mm/h corresponding to a recovery rate of 37% (test of February). In April, the same plot benefited from a higher recovery rate (85%). Yet the protection of this parcel, essentially guaranteed by the vegetal cover, did not reflect a better infiltrability (50 mm/h). This means that the plots covered by vegetation should not be described systematically as infiltrative areas.

Contrary to what is reported by several authors (Alkarkouri *et al.*, 2000; Sabir et Roose, 2004; Sabir *et al.*, 1994; Mosli, 1997), our results do not show a clear relation between infiltration and the ground cover. This can be explained by the presence of an impermeable layer in depth preventing water penetration. The highest infiltrability value (998 mm/h) was recorded in August at the level of P1 plot under direct seeding, north-facing and situated at the bottom of the slope. In fact Indeed, this plot has the largest proportions of opened areas (up to 67%), while the lowest infiltrability (50 mm/h) was measured at the third trial (February) on plot P4, plowed, south-facing, at the top of slope and with a small proportion of opened area (5%). So, it is plot P4 which encourages more runoff. This is due to the high value of the slope that has. This relation shows that the opening of soil such as we visually estimated is a relevant hydrodynamic parameter.

## 6. Conclusion

The study of surface states and infiltration with the factors that control them, have allowed us to identify the hydrodynamic behavior of marly and highlight behaviors influenced by the type of management of these soils and their topographic position. The marl y soils are characterized by a very stable structure and a very variable infiltration in time and space. The measurements on these soils revealed a close link between hydrous and structural dynamics (pore). When these soils are dry, the fissure macroporosity is responsible for the high infiltration. Rain water rushes into the slots that are the preferential flow paths. The obtained results have shown the influence of previous soil moisture on the hydrodynamic behavior. The infiltration varies from 998-344 mm/h for dry soils, from 620 to 50 mm/h for wet soils and from 398 to 38 mm of rain for very wet soil.

Despite their good structural stability, marly soils are very susceptible to erosion because of their particular hydrodynamic behavior. They are affected to alternating moistening and drying (determined by weather) causing a microcracking aggregates. When these soils are cracked, the infiltration is very high and internal erosion can be generated despite the absence of surface runoff. These infiltrations can even encourage mass movements. In a more or less saturated state, the infiltration becomes very low, which consequently easily triggers the runoff, and when infiltration is important, mass movements can be triggered in areas of steep slopes. This study has allowed contributed to the understanding of the dynamics of soil surface by following up of the surface conditions of marl slopes of the study area according to the method of land management throughout the year.

## BIBLIOGRAPHIE

Al Karkouri, J., Laouina, A., Roose, E., Sabir, M., 2000a, Capacité d’infiltration et risques d’érosion des sols dans la vallée des Béni Boufrah – Rif central (Maroc). Bull. Réseau érosion, vol. 20, pp. 342-356.

Benchetrit, M., 1972, L’érosion actuelle et ses conséquences sur l’aménagement en Algérie. PFU, Paris, p. 126.

Boudet, G., 1984, Manuel sur les Pâturages Tropicaux et les Cultures Fourragères, (4e édn, révisée). IEMVT, Maisons-Alfort, p. 266.

Boughalem, M., 2007, Impact des modes de gestion des terres sur la conservation de l'eau et des sols sur les versants marneux de l'Isser-Tlemcen-Algérie. Mémoire de Magister, université de Tlemcen, 109 p.

Boughalem, M., 2013, Impact des systèmes de gestion sur la vulnérabilité des sols à l’érosion; cas du bassin versant de l’Isser-Tlemcen-Algérie. Thèse de Doctorat, université de Tlemcen, 210 p.

Coutadeur, C., Coquet, Y., Estrade, J.R., 2002, Modélisation de l’infiltration de l’eau dans les sols cultivés, 1ères journées scientifiques interdisciplinaires de l'INA (Institut national agronomique). Environnement, écosystème, biodiversité et gestion durable, Paris-Grignon, 9-10 avril 2002, France, pp.1-2.

Daget, P., Bille, J.C., Cora, M., Gaston, A., Konaté, T., 1995, Organisation du suivi de la production végétale dans les pâturages : Exemples du Mali et de l’Ethiopie, Parcours Demain. Numéro spécial. Actes du séminaire international du réseau parcours, Tabarka (Tunisie), 13-15 octobre 1994, 67-71.

Daget, P., Poissonnet, J., 1971, Une méthode d'analyse phytosociologique des prairies, Ann, Agron, INRA, Paris, vol. 22(1), pp. 5-41.

Daget, P., Poissonnet, J., 1991, Prairies Permanentes et Pâturages, Méthodes d'Etude, Inst, Bot, Montpellier, 331 p.

Dumas, J., 1965, Relation entre l'érodibilité des sols et leurs caractéristiques analytiques. Cahiers ORSTOM. Série Pédologie, vol. 3, pp. 307-333p.

Gaston, J., 1992, La production Biologique des Savanes de Côte-d'Ivoire et son Utilisation par l'Homme : Biomasse, Valeur Pastorale et Production Fourragère, CIRAD-IEMVT. Maisons-Alfort, 671 p.

Gascuel-Odoux, C., Heddadj, D., 2000, Maîtrise des transferts de surface dans le contexte armoricain, Bretagne Eau pure, 108 p.

Govers, G., 1991, Rill erosion on arable land in Central Belgium: rates, controls and predictability, Catena, 18, 133-155.

Levy, E.B., Madden, E.A., 1933, The Point Method for Pasture Analysis. N.Z.J. Agr, 46, 267-275.

Mazour, M., 2004, Etude des facteurs de risque du ruissellement et de l'érosion en nappe et conservation de l'eau et du sol dans le bassin versant de l'Isser-Tlemcen, Thèse de Doctorat d'état, université de Tlemcen, 184 p.

McCool, D.K., George, G.O., Römkens, M.J.M., Douglas, C.L., Papendick, R.I., 1993, Topographic effect on erosion from cropland in the northwestern wheat region.Trans. Am. Soc. Agr. Eng, 36, 771-775.

Morsli, B., 1997, Caractérisation, distribution et susceptibilité à l'érosion des sols de montagne ; cas des monts de Béni-Chougrane- Mascara, Mémoire de Magister, INA Alger, 165 p.

Poesen, J., 1984, The Influence of Slope Angle on Infiltration Rate and Hortonian Overland Flow Volume, Z. Geomorph. Suppl, vol. 49, pp. 117-131.

PNUD (Programme des Nations Unies pour le Développement) 2006, L'avenir de l'Environnement en Afrique: notre Environnement, notre Richesse, PNUD, 542 p.

Roose, E., 1996, Mesures de l'infiltration à l'aide de deux simulateurs de pluie dans la vallée de Godim, Compte rendu de mission au Cap Vert, Prodap/Orstom, 10 p.

Roose, E., Blancaneaux, P.H., Freitas, P. 1993, Un test simple pour observer l'infiltration et la dynamique de l'eau dans les horizons du sol, Cah. ORSTOM Pédol, vol. 28, pp. 413-419.

Sabir, M., Roose, E., 2004, Influence du couvert végétal et des sols sur le stock de carbone et les risques de ruissellement et d'érosion dans les montagnes méditerranéennes du Rif occidental, Maroc. Bulletin du Réseau Érosion, vol. 23, pp. 144-154.

Sabir, M., Merzouk, A., Berkat, O., Roose, E., 1994, Effet du pâturage sur l'état de surface, l'infiltrabilité et la détachabilité du sol dans un milieu pastoral aride (Aarid, Haute Moulouya, Maroc). Bull Réseau Erosion, vol. 14, pp. 444-462.