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Use of GIS for Digital Mapping and Spatial Analysis of Landfills: Case of the Settat Province in Morocco

Ghizlane Benezzine[1*], Abdeljalil Zouhri[1], Yahya Koulali[2]

[1] Hassan First University of Settat, Faculty of Sciences and Techniques, Applied Chemistry and Environment Laboratory, Settat, Morocco

[2] Hassan First University of Settat, Faculty of Sciences and Techniques, Laboratory of Biochemistry, Neurosciences, Natural Resources and Environment, Settat, Morocco

* Corresponding author's e-mail: g.benezzine@uhp.ac.ma

ABSTRACT

In Morocco, the population growth and changes in consumption and production patterns are increasing the amount of generated waste, particularly household solid waste. It is estimated at 6.9 million tons per year, of which 5.5 million tons in urban areas, with a ratio of 0.76 kg/inhabitant/day (Ministry of the Interior, national portal for local authorities, National Household Waste Program). In the absence of controlled landfills, this waste negatively affects living spaces and generates health and environmental problems. The province of Settat, which is affected by this scourge, inefficiently manages this household waste as in other regions, thus requiring improvement with the involvement of the actors concerned. This work involves the creation of a cartographic database of household waste in the province of Settat using a Geographic Information System (GIS). The analysis of the maps made, the observation of photos of existing landfills, and a diagnosis of the landfills in the Settat province have shown a direct negative impact on the different vital axes.

Keywords: household solid waste, uncontrolled landfills, environmental management, province of Settat, geographic information system.

INTRODUCTION

On a worldwide scale, the problem of waste management is common. The waste is considered to be worthless as well as a source of nuisance and pollution; therefore, it is disposed of as far as possible in landfills. (Apollinaire TINI, 2003; Durand, 2012). In Morocco, the uncontrolled landfill is the most widespread management method to the detriment of other methods such as composting and incineration. These landfills have negative impacts on humans and the natural environment (Mountadar et al., 2009). In order to remedy this problem, Morocco has initiated several steps and strategies to improve the environmental management sector through the adoption of several laws, notably Law 28-00 on waste management and disposal promulgated by Dahir No. 1-06-153 of 22 November 2006 and published in the Official Gazette No. 5480 on 7 December 2006. This law and its application texts (elaborated by the Ministry of Interior in collaboration with the Department of Environment) introduced planning tools in the solid waste sector and thus imposed the implementation of a national program of household waste PNDM. The main objectives of this program are:

- Protection and preservation, organization of the collection, storage, transport, treatment of waste, planning, information, the definition of responsibilities, control, and sanction.
- The construction of landfills and waste recovery centers for the benefit of all urban centers and the closure and rehabilitation of all uncontrolled landfills by 2022.

Nevertheless, despite all these provisions, it has been noted that the regulatory requirements

for solid waste management provisions have not been applied in some provinces. The province of Settat, located in the central northern part of the Kingdom, is part of the Casablanca-Settat region with an area of approximately 7220 km^2 and 634,184 inhabitants according to the 2014 General Census of Population and Housing (RGPH). It is composed of 46 local authorities. Except for the Commune of Settat, which has delegated the waste management service to a private company, all the other communes in the province manage their waste directly.

This work aimed to develop a diagnosis of the current state of affairs to highlight the problems arising from the current management of household waste in the province of Settat based on the design and analysis of a cartographic database.

MATERIALS AND METHODS

Geographic setting of the province

The province of Settat includes 5 urban communes and 41 rural communes grouped in 3 circles. It is bounded administratively by the provinces of Berrechid and Benslimane to the north, the province of Kalla-Sraghna to the south, the provinces of Fquih Ben Saleh and Khouribga to the east, and the provinces of Sidi Bennour and BenGrir to the west (Figure 1).

Climate

The province of Settat is characterized by a semi-arid continental type climate. Its summers are hot with temperatures from 35°C to 45°C and its winters are cold from 5°C to 15°C. Fluctuating from year to year, rainfall is low, amounting to about 372 mm in an average year (Ben Ouakkass et al., 2018).

Relief

The territory of the Settat province is characterized by a certain physical homogeneity. Indeed, two zones can be distinguished: Lower Chaouia, where the soils are Tirs, and Upper Chaouia, where there is a progressive decrease infertile land. It is made up of limestone plateaus of an accident landscape, reinforced by the spreading of phosphate layers (Icole, 1964).

The geology of the province

The province of Settat belongs to the northwestern part of the phosphate plateau of the Central Moroccan Meseta. It is made up of folded and flattened Hercynian basement soils that outcrop to the north and southwest of the plateau (Ben Ouakkass et al., 2018).

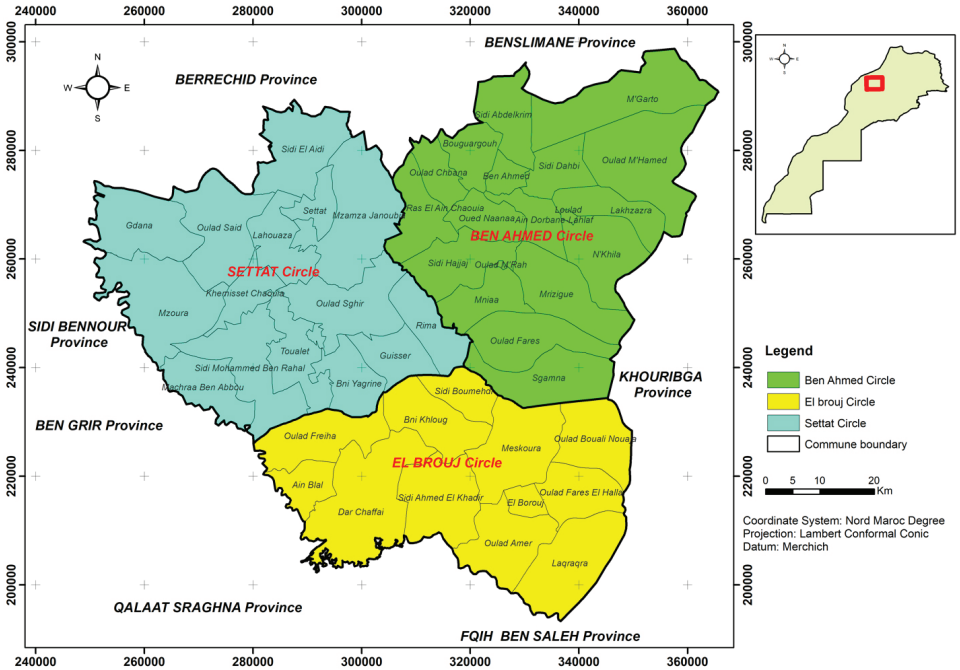

Fig 1. Administrative division of the province of Settat

Study approach

The approach taken for this study is presented as follows:

- Data Collection: Population of the province (High Commission for Planning HCP), the surface area of the commune, number of households, and Quantities of waste (Settat prefecture).
- Retrieving the map of the communes of the province of Settat in shapefile form (SHP) from the Settat prefecture.
- After data collection, the information was mapped using ArcGIS 10.7.1 (GIS) software as follows:
  - A georeferencing of the maps according to a North Morocco degree coordinate system.
  - Creation of layers to define the geographical delimitation of each circle within the province.
  - Combining the attributes (number of populations, number of households, the quantity of waste produced and collected, X and Y coordinates of existing landfills) with the geographical references for each commune.
  - Elaborating the maps of population, location of existing landfills, and the map of waste quantities produced.
  - Providing a layout necessary for each map containing a legend, orientation, a coordinate system, and an adequate scale.
- The observation of the photos of existing landfills, the analysis of the maps produced, and a diagnostic of the current state of the existing landfills enable to highlight the current environmental situation in the province.

RESULTS AND DISCUSSION

Population

Table 1 shows the distribution of the total population over all the communes making up the province of Settat, the number of households, the surface area of each commune, and the population density per commune. The integration of this information into the database made it possible to produce the population map (Figure 2).

The population is concentrated in the urban communes of each circle with 141,637 inhabitants in Settat (chief town of the former Wilaya Chaouia Ouardigha), 32,528 in Ben Ahmed, and 19,229 inhabitants in El Borouj.

Household waste

Uncontrolled landfills in the province are a source of pollution. They are located near cities and sometimes not far from water environments (wadis or groundwater). They produce the leachates that reach surface water and generate direct

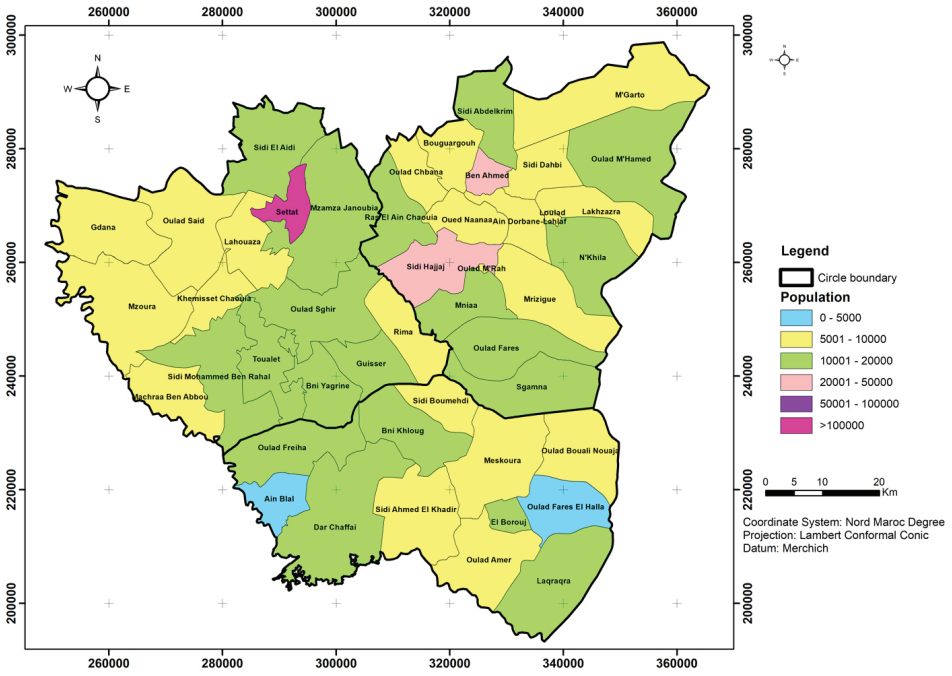

Fig 2. Population of Settat Province

Table 1. Total population of the province of Settat (HCP Haut-commissariat au plan 2014)

Circle	Commune	Population	Households	Area(ha)	Density (hab/ha)
Settat	Settat	141637	32714	60	2361
	Mzamza Janoubia	19576	3485	307	64
	Oulad Sghir	13866	2528	213	65
	Sidi El Aidi	13839	2562	202	69
	Bni Yagrine	13031	2023	125	104
	Guisser	14760	2272	103	143
	Toualet	11976	1925	142	84
	Sidi Mohammed Ben Rahal	10410	1813	224	46
	Mzoura	9525	1855	282	34
	Machraa Ben Abbou	9355	1574	134	70
	Oulad Said	9271	1798	226	41
	Gdana	9084	1669	202	45
	Rima	8949	1473	123	73
	Lahouaza	7394	1368	125	59
	Khemisset Chaouia	5527	1058	78	71
TOTAL		**298200**	**60117**	**2546**	**117**
Ben Ahmed	Ben Ahmed	32528	7222	41	793
	Sidi Hajjaj	20732	3399	153	136
	Ras El Ain Chaouia	14747	2757	130	113
	Sidi Abdelkrim	14008	2273	131	107
	Oulad Fares	12341	1947	183	67
	N'Khila	12306	2082	176	70
	Mniaa	11789	1898	115	103
	Sgamna	10245	1560	192	53
	Oulad M'Hamed	10187	1746	302	34
	Bouguargouh	9539	1543	93	103
	Sidi Dahbi	8703	1572	98	89
	Oulad M'Rah	8697	1746	2	4349
	Lakhzazra	8582	1513	109	79
	M'Garto	8514	1585	282	30
	Mrizigue	8376	1430	192	44
	Ain Dorbane-Lahlaf	8120	1451	80	102
	Oulad Chbana	8081	1319	74	109
	Oued Naanaa	6991	1308	92	76
	Loulad	6049	1209	5	1210
TOTAL		**220535**	**39560**	**2450**	**90**
El Borouj	El Borouj	19229	3841	35	549
	Dar Chaffai	17454	2913	342	51
	Bni Khloug	12930	2290	160	81
	Oulad Freiha	11581	1838	179	65
	Laqraqra	11419	1833	231	49
	Sidi Ahmed El Khadir	9687	1404	201	48
	Meskoura	7180	1113	222	32
	Oulad Amer	6673	1081	179	37
	Oulad Bouali Nouaja	6507	1065	162	40
	Sidi Boumehdi	5081	797	86	59
	Ain Blal	4699	906	81	58
	Oulad Fares El Halla	3021	525	128	24
TOTAL		**115461**	**19606**	**2006**	**58**

negative impacts on public health and the environment (Khattabi et al., 2007). Figure 3 shows the location of the existing landfills in the province of Settat with three landfills in the Settat circle, four landfills in the Ben Ahmed circle, and only one landfill in the Elbrouj circle.

Table 2 summarizes the quantities of household waste produced, collected, and the collection rate by urban and rural areas in the province of Settat. A large amount of waste is found in the urban area because of the high density of the population in these municipalities.

Figure 4 shows the amount of waste generated in the province. The city of Settat ranks first in the production of household waste with a quantity of about 133 T/day, which represents 34% of the waste produced at the provincial level. The collection rate at the provincial level is about 58%, with a rate of 86% in urban areas and 2% in rural areas.

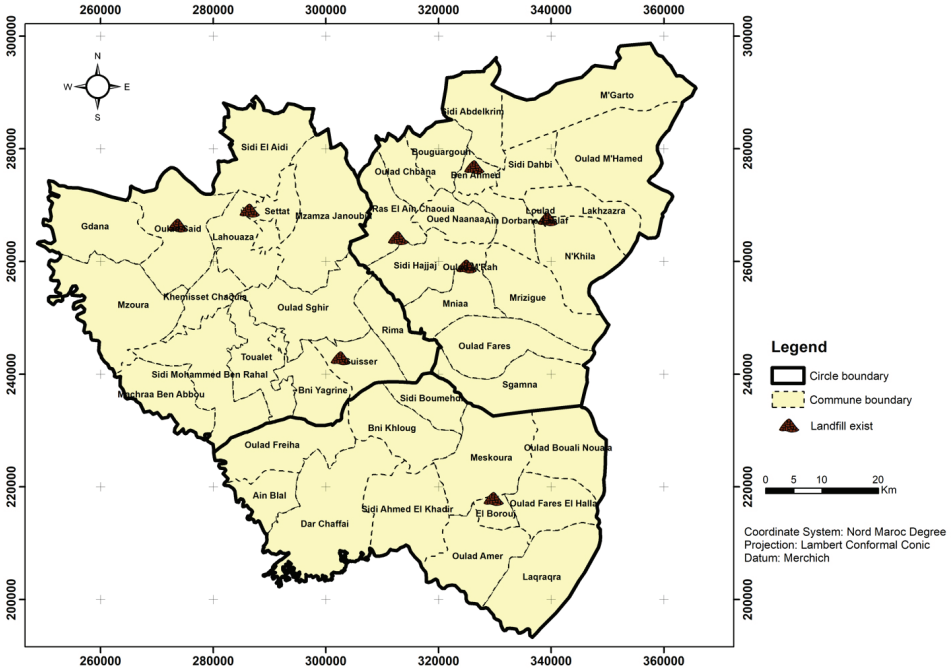

Fig 3. Location of existing landfills in the province of Settat

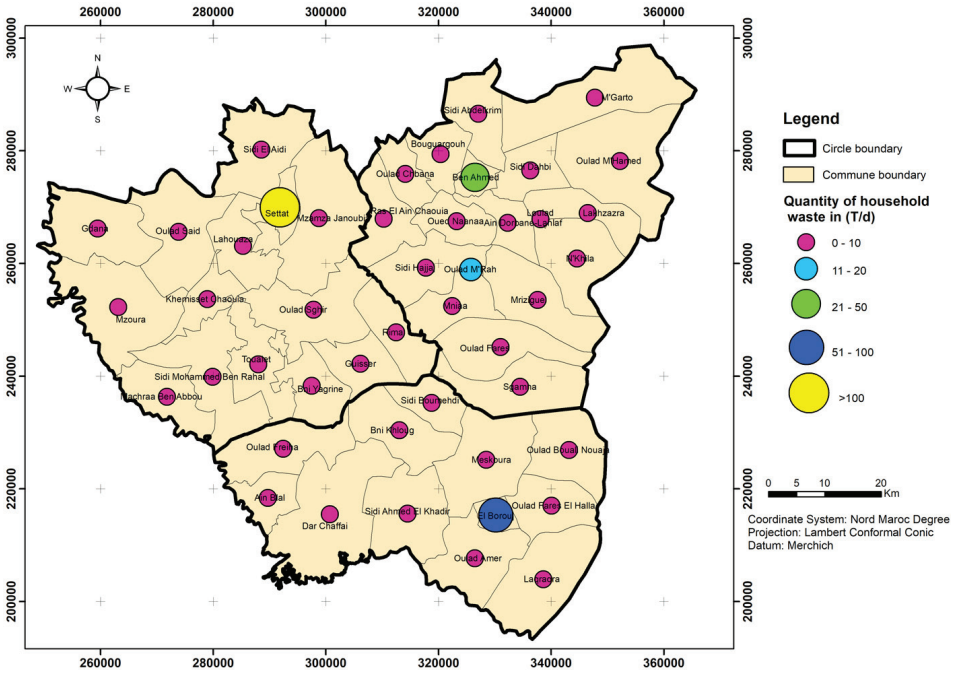

Fig 4. Quantity of household waste in (T/d) in the Province of Settat

Table 2. Quantity of waste in the province of Settat (Settat prefecture)

Communes	Tonnage produced in T/j	Tonnage collected in T/j	Collection rate in %
Urbain perimeter			
Settat	132.682	129.763	97.80
El Borouj	73.476	54.519	74.20
Ben Ahmed	25.3	18.697	73.90
Oulad M'Rah	12.852	11.207	87.20
Loulad	8.591	5.661	65.90
Ras El Ain	1.21	0.038	3.10
Guisser centre	0.98	0.715	73.00
Oulad Said CENTRE	0.78	0.428	54.90
TOTAL	**255.871**	**221.028**	**86.38**
Rural perimeter			
Mzamza Janoubia	7.23	0.04	0.60
Sidi Hajjaj	6.25	0.03	0.50
Ain Dorbane-Lahlaf	5.99	0.04	0.60
Dar Chaffai	5.41	0.02	0.30
Sidi Abdelkrim	5.04	0.04	0.70
Ras El Ain Chaouia	4.67	1.14	24.50
Guisser	4.40	0.77	17.40
Oulad Sghir	4.07	0.02	0.50
Bni Yagrine	4.04	0.00	0.00
Bni Khloug	3.93	0.11	2.70
Sidi El Aidi	3.85	0.01	0.30
Toualet	3.78	0.00	0.10
Oulad Fares	3.67	0.03	0.90
N'Khila	3.53	0.04	1.00
Oulad Freiha	3.42	0.02	0.60
Sidi Mohammed Ben Rahal	3.33	0.12	3.70
Mniaa	3.31	0.01	0.40
Laqraqra	3.19	0.01	0.30
Oulad M'Hamed	3.10	0.02	0.50
Sidi Ahmed El Khadir	3.02	0.01	0.20
Sgamna	3.01	0.00	0.10
Mzoura	2.96	0.01	0.40
Bouguargouh	2.90	0.01	0.50
Machraa Ben Abbou	2.88	0.00	0.00
Gdana	2.72	0.02	0.70
M'Garto	2.56	0.01	0.20
Sidi Dahbi	2.55	0.02	0.70
Oulad Chbana	2.55	0.00	0.10
Mrizigue	2.54	0.00	0.10
Rima	2.50	0.02	0.80
Lakhzazra	2.48	0.00	0.10
Meskoura	2.46	0.01	0.30
Oulad Said	2.15	0.33	15.30
Lahouaza	2.15	0.03	1.20
Oulad Fares El Halla	2.06	0.00	0.00
Oulad Amer	1.89	0.01	0.40
Khemisset Chaouia	1.69	0.00	0.00
Ain Blal	1.54	0.01	0.40
Sidi Boumehdi	1.32	0.01	0.40
Oulad Bouali Nouaja	0.92	0.01	0.60
Oued Naanaa	0.10	0.00	0.30
TOTAL	**131.16**	**2.96**	**2.25**
TOTAL PROVINCE	**387.031**	**223.984**	**57.87**

Table 3. Mode of household waste disposal in % (HCP Haut-commissariat au plan 2014)

Communes	Communal garbage bin (%)	Communal or private truck (%)	Other (%)
Urbain perimeter			
Settat	72.7	25.1	2.3
El Borouj	41.2	33	25.9
Ben Ahmed	10	63.9	26.1
Oulad M'Rah	79.9	7.3	12.7
Loulad	65.6	0.3	34.1
Ras El Ain	0.5	2.6	97
Guisser centre	47.1	25.9	27
Oulad Said CENTRE	21.8	33.1	45.1
Rural perimeter			
Mzamza Janoubia	0.50	0.10	99.30
Sidi Hajjaj	0.40	0.10	99.50
Ain Dorbane-Lahlaf	0.30	0.30	99.40
Dar Chaffai	0.10	0.20	99.70
Sidi Abdelkrim	0.50	0.20	99.30
Ras El Ain Chaouia	1.10	23.40	75.50
Guisser	11.30	6.10	82.60
Oulad Sghir	0.40	0.10	99.40
Bni Yagrine	0.00	0.00	100.00
Bni Khloug	0.60	2.10	97.30
Sidi El Aidi	0.10	0.20	99.80
Toualet	0.10	0.00	99.90
Oulad Fares	0.40	0.50	99.10
N'Khila	0.20	0.80	98.90
Oulad Freiha	0.20	0.40	99.30
Sidi Mohammed Ben Rahal	0.30	3.40	96.40
Mniaa	0.30	0.10	99.60
Laqraqra	0.10	0.20	99.70
Oulad M'Hamed	0.10	0.40	99.50
Sidi Ahmed El Khadir	0.10	0.10	99.90
Sgamna	0.00	0.10	99.90
Mzoura	0.20	0.20	99.60
Bouguargouh	0.20	0.30	99.50
Machraa Ben Abbou	0.00	0.00	100.00
Gdana	0.30	0.40	99.30
M'Garto	0.10	0.10	99.90
Sidi Dahbi	0.60	0.10	99.30
Oulad Chbana	0.00	0.10	99.90
Mrizigue	0.00	0.10	99.90
Rima	0.30	0.50	99.20
Lakhzazra	0.10	0.00	99.90
Meskoura	0.30	0.00	99.70
Oulad Said	6.10	9.20	84.80
Lahouaza	0.50	0.70	98.80
Oulad Fares El Halla	0.00	0.00	100.00
Oulad Amer	0.20	0.20	99.60
Khemisset Chaouia	0.00	0.00	100.00
Ain Blal	0.10	0.30	99.60
Sidi Boumehdi	0.10	0.30	99.60
Oulad Bouali Nouaja	0.20	0.40	99.40
Oued Naanaa	0.10	0.20	99.70

It should be noted that in the rural areas, the douars do not benefit from any services to manage the waste produced: organic waste is reused to feed livestock and the animal excrement is used as fertilizer. The broken metals, wood, plastic, and cardboard are used in the consolidation of dwellings and traditional ovens and hammams.

Mode of disposal of household waste

Table 3 shows how household waste is disposed of. The most important mode is the communal bin. The Figure 5 shows that the landfills in the province exist on the edges of agricultural fields and near houses, wells, chaâbas, thus causing visual nuisances, fire hazards, an increase in black spots, the affectation of soil fertility, loss of livestock, and degradation of the ecological value of certain natural sites. This situation thus causes several nuisances on the landscape aspect, as well as risks of contamination of surface and groundwater. Table 4 provides a description and diagnosis of the current state of landfills in the province of Settat.

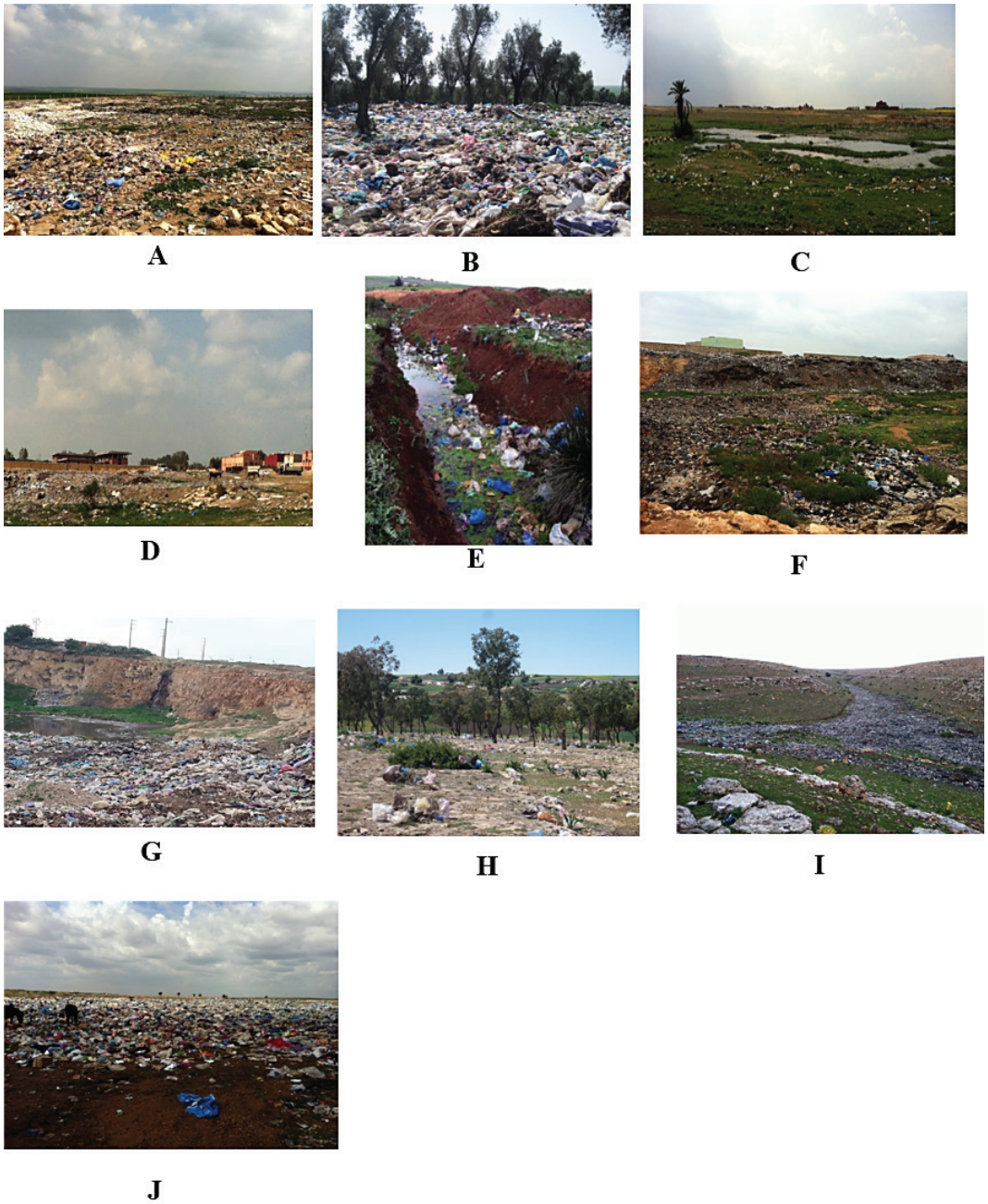

Fig. 5. Photos of Landfills; (A) Settat, (B) Oulad, (C); (D) Guisser, (E) Ben Ahmed, (F) Oulad Mrah, (G) Loulad, (H) Ras el ain, (I); (J) El Brouj

Table 4. Diagnosis of the current state of landfills in the province of Settat

Circle	Commune	Area (ha)	The thickness of waste (m)	Diagnosis
Settat	Settat	32.5	2.5	• Discharge 7 km from the center. • Presence of houses near the dump. • Existence of reclaimers exposed to health risks in the landfill. • Existence of livestock and dogs inside the landfill.
	Guisser	1	0.5 – 2.0	• Landfill near the center of the town. • Existence of a wetland that stores the leachate below the site.
	Oulad Said	0.2	1.0	• Discharge 200 m from the center. • Existence of odors, smoke, plastic bags, visual pollution. • Existence of population and agricultural land • nearby.
Ben Ahmed	Ben Ahmed	6	0.5 – 2.0	• Landfill is located 5 km from the center. • Existence of two châabas near the dump. • Existence of a well downstream of the dump was condemned by the inhabitants because suspected of being contaminated.
	Ras El Ain Chaouia	2	0.5 – 2.0	• Landfill is located 2.5 km from the center. • Existence of three wells abandoned by the inhabitants near the dump. • Existence of smells, smoke, plastic bags, visual pollution.
	Ouled M'Rah	2	1.0	• Landfill is located 1.5 km from the center. • Existence of houses next to the dump. • Existence of a wadi that drains the city's wastewater and flows below the landfill site and also receives the leachate in case of rain.
	Loulad	0.5	1.0	• Discharge is located 1km from the center. • The landfill receives a wastewater discharge that is • mixed with household waste-producing • more leachate.
El Brouj	El Brouj	10	0.5 – 2.0	• Landfill is located 5 km from the center. • Existence of a wadi at the bottom of the landfill filled with directly dumped waste.

Recovery activities

Informal waste recovery is an aspect of household waste management that is present in the Settat province, as well as in other areas (Makamté Kakeu-Tardy, 2018). Recovered waste is generally reused in two ways:

- For subsistence and livestock feed.
- For resale, which allows objects to be reintroduced into the economic circuit (for example, paper, cardboard, iron, cans, glass, plastic, aluminum, and rubber).

Sorting/recovery of waste is a sector that concerns the entire chain from the garbage cans and containers to the landfill. Thus, this activity, despite its defects, makes it possible to:

- Valorize a non-negligible quantity of waste.
- Reduce the volumes of waste sent to landfills.
- Recover non-biodegradable waste.
- Guarantee a source of income for many underprivileged families.

However, if this recovery is carried out by sorting and collecting waste at the source, the results in terms of recovery and especially in terms of preserving the health of the population would be greater.

CONCLUSIONS

This study has established the current mode of household waste management, which influences the environmental quality of the Settat province as well as directly impacts the population and the natural environment of the province. The results have shown the urgency to take the decision to move to the effective implementation of planning tools under the national household waste program PNDM and thus to consider the creation of waste transfer centers in the territory of the Settat province and an inter-municipal landfill that will only receive non-recoverable waste. A questionnaire, intended for the various administrations and the

population concerning the modalities of sorting, collection, and recovery of waste from households to the landfill, is being prepared.

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