

Chapter 9

Soil crusting and sealing in West Africa and possible approaches to improved management

Crusts are thin soil surface layers more compact and hard, when dry, than the material directly beneath. They hamper seedling emergence, reduce infiltration and favour runoff and erosion. Seal is generally the term given to a wet crust. Both crusts and seals are formed in the same way so no further distinction will be made in this paper. The term crust is preferred and is used from here on.

The first works mentioning soil crusts in West Africa mainly refer to dry areas: Mauritania (Audry and Rossetti 1962), Senegal (Aubert and Maignien 1948), Mali (Leprun 1978), Burkina Faso (Roose 1973), Niger (Boulet 1966), northern Nigeria (Sombroek and Zonneveld 1971), Tchad (Bocquier 1971) and Cameroon (Martin 1960). In these regions crusts affect most of the grazed and cropped land. Due to the drought combined with animal and human pressure, surface crusts have extended considerably in the last twenty years (Gavaud 1990), being at the same time a factor in, a result of, and indicator of desertification (Valentin and Casenave 1990). Studies in the wet savannah and in the forest zone are more recent. Here they are more strictly associated with agricultural activities. The experience gained in the Sahel (Collinet and Lafforgue 1978; Casenave and Valentin 1989) facilitated the identification of crust problems in cropped land in the wet savannah (in Cote d'Ivoire, Camara 1989, and in Togo Poss *et al.* 1990) and in the rainforest (Collinet 1988a; Hartmann 1991).

The main objectives of this paper are:

- to draw attention of agronomists to the widespread problem of surface crusting in West Africa;
- to present the main results gained in research;
- to propose ways to prevent and combat crusting.



PLATE 7 Structural crust, slaking type, developed on a 'mound' in a clay loamy soil in northern Niger under simulated rainfall. Note the surface roughness. Depositional crusts are formed under the water layer



PLATE 8 Structural crust, two-layered sieving type, developed in a sandy soil in southern Côte d'Ivoire. Note the fine sand layer between the coarse sand layer and the fine particle layer

TYPES OF SOIL CRUSTS

Generally, two main types of crust are distinguished by their mode of formation (Chen *et al.* 1980): structural crusts and depositional crusts. The former develop *in situ* whereas the latter are formed of particles which have been transported from their original location. Detailed studies in West Africa (Casenave and Valentin 1989; Bresson and Valentin 1990; Valentin 1991) have led to a more comprehensive classification, which, though it was first developed for the arid and semi-arid zones, has been then applied satisfactorily in wetter climates in cropped land of the wet savannah zone (Valentin and Janeau 1990; Poss *et al.* 1990) and rainforest areas (Hartmann 1991).

Structural Crusts

In West Africa, two main types of structural crusts commonly occur depending on the texture of the top layer.

Slaking crusts

These crusts consist of a layer made of fine particles with rougher patches of partly broken down clods (Plate 7). These are marked by a generally higher surface and are more porous than the surrounding depressions where depositional crusts develop (Falayi and Bouma 1975; Valentin 1981; Levy *et al.* 1988; Pleuvret 1988; Valentin 1991). Slaking crusts form when soils contain enough clay (> 15-20%) to entrap and compress air during wetting so that aggregates break down. The process can also involve swelling and infilling. Since slaking crusts are formed primarily by wetting, they can develop even when the soil is protected from rainfall impact (Valentin and Ruiz Figueroa 1987).

Sieving crusts

Sieving crusts are formed of a layer of loose sand overlaying a thin layer of finer material (Plate 8). In the most developed form, the crust can consist of three well-sorted layers. The uppermost is composed of loose, coarse sand, the middle one consists of fine densely packed grains with vesicular pores, and the lower layer shows a higher content of fine particles with reduced porosity (Plate 9). This lower layer causes the low infiltrability (0-15 mm h⁻¹) of the crust (Casenave and Valentin 1989 and 1992). The textural differentiation results from a sieving process. Water drop impact forms micro-craters, the walls of which present a clear, vertical sorting of particles (Valentin 1986a). Moreover, percolating water may enhance the downward movement of clay through the upper sandy layers. Clay particles can accumulate due to entrapped air within the underlying layers during infiltration (Collinet 1988b). This type of crusting mainly affects sandy and sandy-loam soils. Sieving crusts, also referred to as “filtration pavements” or “layered structural crusts”, have been recognised in untilled soils in northern Niger (Valentin 1981), and in tilled soils in southern Togo (Poss *et al.* 1990) and the southern Côte d’Ivoire (Hartmann 1991).

A particular form of sieving crust is the **pavement crust** (Plate 10) where coarse rock fragments are embedded in the crust, the microstructure of which is very similar to the sieving crust with three layers. Vesicular porosity is very pronounced especially underneath the incorporated coarse fragments. Infiltrability is extremely poor (0-2 mm h⁻¹) (Casenave and Valentin 1989 and 1992). These crusts range from the Sahara where this surface condition is named desert pavement or “reg”, to the dry savannah zone.



PLATE 9 Structural crust, three-layered sieving type, in Central Burkina Faso. Note the fine sand layer between the coarse sand layer and the fine particle layer



PLATE 10 Pavement crust, Yatenga region, Burkina Faso. Note the coarse fragments included in a crust similar to that of Plate 9

Erosion Crusts

Erosion crusts form barren patches of land (Plate 11), well-known by West African farmers or pastoralists, who give them various names: “zipelle” or “vuigo” in Central Burkina Faso, “white soil” or “glade” in More, “harde” in Foulani in northern Cameroon, and “naga” in Chad (Pias 1970).

These crusts are built up as a smooth and hard layer made of fine particles. Porosity is restricted to a few cracks and vesicles. Infiltrability is very poor ($0\text{-}2\text{ mm h}^{-1}$) (Casenave and Valentin 1989 and 1992). Erosion crusts develop from both forms of structural crusts. They are formed from slaking structural crusts which have been smoothed and enriched in fine particles, and from sieving crusts where the loose sandy layers have been removed by overland flow or wind (Valentin 1985).

As observed in Mauritania (Barbey and Couté 1976), in Mali (Rietveld 1978), in Niger (Valentin 1981) and in Chad (Dulieu *et al.* 1977), erosion crusts can locally be strengthened by algae (*Cyanophyceae*). They can then form pedestal features where the surrounding weaker uncolonized erosion crust has been eroded (Casenave and Valentin 1989).

These algae are thought to be responsible for the low infiltrability of crusted sandy soils because they are hydrophobic. However, the physical binding effect of hyphae is of greater importance to infiltration. It has been observed that the hydrophobic tendency often disappears following rainfall: a few millimetres in the Sahelian zone (Rietveld 1978), a few tenths of millimetres in the rainforest zone.

Depositional Crusts

Most often depositional crusts are built up with a combination of runoff and “still” depositional crusts.

Runoff depositional crusts

These are characterized by alternate very thin layers contrasting in texture. These crusts can be up to a few centimetres thick, especially when they develop between two ridges or under furrow irrigation. Almost invariably, they overlie structural crusts with which they have sharp boundaries (Bresson and Boiffin 1990; Boiffin and Bresson 1987). Their infiltrability is much lower than that in the “mounds” of slaking crusts (Falayi and Bouma 1975; Valentin 1981; Levy *et al.* 1988; Pleuvret 1988; Valentin 1991). Runoff depositional crusts are formed by sediments deposited in overland flow.

Still depositional crusts

These consist of densely packed and well-sorted particles, the size of which progressively increases with depth. The vertical particle size distribution, with coarser particles at the bottom and finer particles at the top, is the reverse of that observed in the sieving crusts. When dry, these crusts often break into curled-up plates. Still depositional crusts form in standing water where the larger particles sink rapidly to form the bottom layer, and the finer particles are deposited at the top. Infiltrability of still depositional crusts is poor ($0\text{-}7\text{ mm h}^{-1}$) (Casenave and Valentin 1989 and 1992). The frequent, wide cracking common in these crusts favours seedling emergence. Algae may develop on these crusts (Plate 12).



PLATE 11 Erosion crust capping a barren patch in northern Cameroon. Note that wind-drifted sand accumulates where vegetation can maintain itself. In turn, vegetation develops only where surface conditions are favourable enough for seedling emergence and water infiltration



PLATE 12 Still depositional crust near Niamey, Niger. Note that curling plates have been colonized by dark cryptogams

Salty Crusts

Salty crusts are not extensive in West Africa and occur mainly near the sea or in the vicinity of lakes. They have some economic importance as a source of salt (Paradis 1980). In the Sahel, animals lick the ground in specific locations. For a few days, they stay near these so-called “salt licks” to take up their annual supply of minerals (Leprun 1978).

A range of minerals is found in such crusts. White saline crusts mainly consist of sodium and magnesium chlorates and sulphates. They are usually affected by wind erosion as they dry. Black saline crusts contain sodium carbonate combined with organic matter (Aubert 1976). Some yellow saline crusts may develop on very acid sulphate soils, like those studied by Le Brusq *et al.* (1987) in the Sine Saloum, Senegal. They are composed of aluminium, iron and magnesium sulphates. Sulphate crusts are generally the least porous to evaporating water and sodium chloride crusts are the most porous (Galizzi and Peinemann 1989).

White saline crusts are found in Mauritania (Audry and Rossetti 1962); in Gourma, Mali (Leprun 1978); in the vicinity of Lake Chad, namely in southern Niger (Gavaud 1975); in northern Cameroon (Brabant and Gavaud 1985) and in Chad (Pias 1970). Since most of these soils are clayey and sedimentary, these crusts are rather similar to sedimentation crusts, with polygonally shaped cracks. However, they can evolve in the dry season into a loose, powdery layer, as observed in northern Senegal (Mougenot 1983).

EFFECTS OF CRUSTS

Soil and Water Losses

Water infiltration reduction

Crust formation markedly reduces the macroporosity of the soil surface layer. Since water infiltration into soil varies as the fourth power of the diameter of the pores, the impact can be very strong. The first study of the effects of crust formation on infiltration was presented in the USA by Duley (1939).

The double-ring infiltrometer was used in West Africa by Wilkinson and Aina (1976) to study the effect of surface crusting on water intake. Most authors consider this well-known method as unsatisfactory (Lafforgue and Naah 1976; Valentin 1981; Poss and Valentin 1983; Stroosnijder and Hoogmoed 1984; Valentin 1988). These workers note that:

- installation of the equipment results in a partial destruction of the surface crust;
- the double-ring uses a greater height of water than that under natural circumstances;
- the water layer used may cause slaking and processes other than those observed under rainfall;
- the unrealistic conditions give results different to those obtained under rainfall;

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