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Hydromorphism — Its definition and correlation between three major classification systems with reference to West Africa

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ABSTRACT

Hydromorphic soils may be defined simply as any wetland soil that will not support crops (or plants), with aerobic edaphic requirements, during the peak of the groundwater recharge. The influence of the water-table is largely controlled by the texture of the profile. This is of significance because the capillary fringe of any water-table may be as saturated as those horizons under the water-table, and this tends to increase the height of the groundwater. A depth of 100 cm. to a saturated zone is suggested as the depth below which a pedon ceases to become aquic or show features associated with hydromorphism that could limit the environment to anaerobic crops. For a general landuse purpose, a probable depth of 150 cm. is suggested as the depth beyond which a pedon ceases to become hydromorphic. Because hydromorphism does not preclude those soil forming processes peculiar to the well-drained upland soils, classification as outlined in Soil Taxonomy (USDA) could be appropriate for the classification of hydromorphic soils. The aquic prefix points to the influence of the water regime on the pedogenesis and properties of the soils concerned. Attempt at correlating the three systems, viz., USDA, FAO–UNESCO and French was made.

Introduction

Hydromorphic soils may be some of the most important soil resources of the world awaiting full utilization for food production. This is true of the wetter tropical and subtropical zones of Africa where precipitation is normally not a limiting factor to crop production. However, precipitation is a limiting factor to production in the Sudan and Sahel Savannas. The wetlands in West Africa have become centres for farming populations as is evident in the Fadamas, in the inland delta of River Niger at Mali, and in the lowlands of Upper-Volta.

To estimate the relative proportions of hydromorphic and other soils along West Africa, delineating criteria have to be properly defined and accepted universally or at least regionally. This is necessary so that technology transfer can be used without reverting to the trial and error of some agricultural projects.

Definition

Hydromorphic soils virtually mean the same to all soil scientists in terms of morphological and chemical properties, however the different classification systems are still not very interchangeable because their criteria for classification are based on different premises.

In West Africa, the definition of hydromorphic soils can be related to three different schools of classification, viz.; the USDA (1975), FAO–UNESCO (1974), Aubert (1965, 1968) and D'Hoore (1964). Aubert's and D'Hoore's definitions can be jointly called the French system since they are very similar.

According to Soil Taxonomy (Soil Survey Staff, 1975) there are five soil moisture regimes, but these different moisture regimes can be regrouped into three major categories in terms of pedological significance, that is:

(a) the soil is saturated most of the year
(b) the soil is saturated for brief periods but the amount of water is sufficient to cause leaching and
(c) the soil is never saturated and no leaching occurs.

The first category belongs to the aquic moisture regime and defines hydromorphic soils whether this moisture regime affects the whole profile or just the solum or part thereof. The solum is defined by the lowest limit of the rooting depth of the native perennial plant. Soil Taxonomy (USDA, 1975) further defines that a soil or horizon is saturated with water when water stands in an unlined borehole close enough to the soil surface or the top of the horizon so that the capillary fringe[1] reaches the surface or the top of the horizon in question. The soil moisture regimes as used by USDA have the assumptions that the soil is supporting whatever vegetation is capable of supporting, that is, crops, grass or native vegetation, and the moisture content is not influenced by either fallowing or irrigation.

The aquic (L. aqua, water) moisture regime is one of the classes of soil moisture regimes defined by Soil Taxonomy. It implies a reducing regime that is virtually free of oxygen. For differentiation in the highest categories of Soil Taxonomy, the whole profile must be saturated, but for subgroups only the lower horizons need be saturated. In situations where ground-water is always at or very close to the surface, which is always the situation for the inland swamps and mangrove swamps, the moisture regime of the latter is called "peraquic." This has only been used in a descriptive sense to aid soil genesis study and has not been used as a formative name in classification. The term "aquic" seems to be adequate when used at several levels in the hierarchical system of Soil Taxonomy.

The FAO/UNESCO (1974) definition and classification of hydromorphic soil contained in the Soil Map of the World (Volume 1) has much in common with USDA definition. Quantitatively both use the same criteria with regard to when a soil is considered saturated (bore hole and stable color dye). Qualitatively they differ. The FAO/UNESCO definition emphasizes the concept of gleization, which is the process that gives the morphological character to profiles with a permanent or intermittent saturated condition. Gleysols and the gleyic groups constitute the major hydromorphic soils of the FAO/UNESCO map. Gleysols are those strongly influenced by groundwater and the gleyic groups "constitute soils of which only the lower horizons are influenced by groundwater, or which have a seasonally perched watertable within the profile."

D'Hoore (1964) classified hydromorphic soils into:

(1) mineral hydromorphic soils and
(2) organic hydromorphic soils.

D'Hoore defined mineral hydromorphic soils as:

> soils, other than vertisols and similar soils, whose development and characteristics (presence of gley and/or pseudo-gley in at least one of their horizons) are influenced by permanent or seasonal waterlogging.

Organic hydromophic soils are insignificant in West Africa. They do however occur mainly in the mangrove swamps.

"CLASSE X" of the French system of classification as enunciated by Aubert (1965) consists mainly of "Sols Hydromorphes" divided into three "sub-classes." While the first two sub-classes are not useful, for the same reason as given for D'Hoore's second unit, the third, "Sous–Classe 3: Sols hydromorphes mineraux ou peu humiferes" is very related to the type of hydromorphic soils under consideration.

[1] SSSA glossary (1978) defines capillary fringe as the zone just above the water table, i.e., zero gauge pressure, that remains almost saturated.

Gley and pseudo-gley terms play prominent roles in the definition of the French hydromorphism, where pseudogley refers to a condition of fluctuating water-table.

It is said that the French system is almost identical to the Belgian (D'Hoore specifically) though their regions of operation had been different. While D'Hoore got much involved in Central Africa, the French concentrated in West Africa (of the fourteen countries that constitute West Africa, only four are English-speaking, while the rest, except Portuguese Guinea, are French speaking).

As far as it is known no extensive work has been done to trace how far the rooting medium of the perennial plants (wild rice inclusive) extends in the wetland soils. The capillary fringe as used by the USDA (1975) is taken into consideration in the definition of hydromorphism. It is difficult to generalize on the quantitative depth or height of water-table using the capillary fringe, because its extent varies with the soil texture, the density and the distribution of the roots of the locally adapted crop. The concept of a saturated zone is being considered as an alternative to 'water table' plus 'capillary fringe' (Rust, personal communication). More work is still required on this concept.

After working on a toposequence in southwest Nigeria, Moormann et al. (1977) stated that a ground water table below 50 cm. has no positive effect on lowland rice yield. FAO/UNESCO (1974) used 100 cm. as the control depth. Arbitrarily using 150cm. as the maximum control depth, hydromorphism or hydromorphic soils can then be defined as the properties exhibited in the soil profile, or in the horizons, by either the permanent water-table ("peraquic," "gley," "ground-water gley") or by a temporary period of saturation ("aquic," "pseudogley," "surface-water gley"). And because Vertisols along West Africa are also subjected to seasonal waterlogging (Pseudogleys), they together with all the vertic subgroups, subunits, or subclasses exhibit properties of hydromorphism and therefore come under the regime of hydromorphic soils. Whenever excess moisture is the most important limiting factor in land-use for crops requiring aerated soils, such areas will come under the realm of hydromorphism.

All soils that can sustain upland (well-drained) aerobic plants at the peak of the groundwater recharge period are non-hydromorphic. Soils with saline or alkali characteristics are excluded from the definition, since the waterlogged occurrence under these two soil conditions are more of a result of the chemical nature of the soil components.

Classification

According to the definitions above, classification systems as given by the proponents of taxonomic concepts will be given here and, where possible, correlation between the systems will be shown.

The USDA (1975) taxonomic units applicable to the hydromorphic soils in West Africa are Aquents, Aquepts, Aquolls, Aquods, Aqualfs, Aquults, Aquox and Uderts, all exhibiting features of gleying. These imply that the soils belong to the order prefixed by "Aqu," a shortened form of "Aquic." These units are suborders in soil taxonomy. Soil taxonomy further explains that, in the absence of any diagnostic horizon that would reflect the influence of soil moisture and temperature, the *regime* (either moisture or temperature) defines the taxa.

The French classification as enumerated by Aubert (1965, 1968) distinguishes three sub-classes (Sous Classe) of hydromorphic soils, viz:-

(1) sols hydromorphes organiques
(2) sols hydromorphes mozennement organiques
(3) sols hydromorphes mineraux ou peu humiferes.

The mangrove swamps along the West African coastline may belong to Aubert's (1965) "Sols Humiques a Gley (parfois denommes "Sols-Torbeux"), which is the only group in "Sous-Classe 2" of the French system. The third class (3), is the only relevant one to West African environment.

"Sous-Classe 3" is subdivided into three groups as shown below and then divided into sub-groups. Under this sub-classes, groups (a) and (b) will be particularly relevant while group (c) may occur in some areas of the Sudan and Sahel savannas due to dryness. Generally, this sub-class will consist of hydromorphic soils with a very low content of organic matter, < 10% in the top 10 cm, and generally less than 4 to 5% (Aubert, 1965). A division of subclasse 3 into groups a and b is as follows:

* Groupe a– Sols hydromorphes peu humeferes a gley

  Sous-groupes:
  * Sols a gley de surface ou d'ensemble
  * Sols a gley de profoundeur
  * Sols a gley sales
  * Sols a gley lessives

* Groupe b– Sols hydromorphes peu humiferes pseudogley

Sous-groupes:
* Sols a taches et concretions
* Sols a carapace ou cuirasse.

Group c is Sols hydromorphes peu humiferes a redistribution du calcaire et du gypse. The basic difference between the above groups is that the soils in Group a are due mainly to a high groundwater table (gley) while the soils in group b are due to a perched watertable (pseudogley).

Gleization is a predominant process with great influence in the French classification of the hydromorphic soils in West Africa. While "Sols a gley de surface ou d' ensemble" will typify a flooded soil or highly saturated soil at least up the base of the A1 horizons, "Sol a gley de profoundeur" typifies a deep groundwater table but still within sufficient range to influence crop growth. "Sols a gley sales" is a salty surface horizon that may not be of sufficient concentration to limit crop growth. "Sols a gley lessives" is an equivalent of Aqualf or Aquult by definition (see Table 1).

Vertisols and Paravetisols were previously included in the hydromorphic class (Classe IV of Aubert, 1965). These soils, due to structural property and topographic position, are seasonally saturated and thus exhibit "gley" and "pseudogley" properties. Soil structure and topographic criteria have been the differentiae used in the division of "Class IV" into sub-classes. "Vertisols et Paravertisols Topomorphes (ou Topo-Lithomorphes)" is a hydromorphic sub-class because of its position in the landscape, while the second sub-class, "Vertisols et Paravertisols Lithomorphes" inherits its hydromorphic properties due to the presence of expanding 2:1 clay minerals (the smectite group) though it is usually situated relatively high on the landscape.

Both FAO/UNESCO (1974) and D'Hoore (1964) classifications do not have as many categories as that of Soil Taxonomy (USDA, 1975) and the French system (Aubert, 1965, 1968). The former two can be said to be monocategorical and may be used as a mapping legend if so desired. The word "Gley" (Russian word for mucky soil mass) is very important in the FAO/UNESCO classification of mapping units. Gleysols are all hydromorphic soils while the word "Gleyic" serves as an adjective to other units and it connotes hydromorphic properties. According to Soil Taxonomy, the following will be found along West Africa, and, where possible, correlations between the French, USDA and FAO/UNESCO systems are shown (Table 1).

D'Hoore's (1964) classification appears very simple for hydromorphic soils and his classification scheme is equivalent to his mapping legend. Most related to this discussion are D'Hoore's Mineral Hydromorphic Soils," which also have many associated units. The one (BoNa) with juvenile soils on riverine and lacustrine alluvium, is the most widely distributed (D'Hoore, 1964).

Moormann and van Breemen (1978) classified hydromorphic soils according to their position on the landscape, fluxial and phreatic soils. This does not however replace the conventional classification systems as discussed earlier.

Because of the hierarchical system used in Soil Taxonomy (USDA, 1975), the dominant influence of the soil water regime can be introduced in the classification at several levels. Most of the hydromorphic soil bodies of the world, in their natural state, alternate between wet and dry cycles, that is, there are pedogenetic processes typical of anaerobic and aerobic soil environments going on throughout the soils' pedologic life cycles. This makes Soil Taxonomy (USDA, 1975) more relevant to the classification of hydromorphic soils.

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TABLE 1

CATEGORIES OF HYDROMORPHIC SOILS AS DEFINED BY FAO/UNESCO(i), FRENCH(ii) AND USDA SOIL CLASSFICATION SYSTEMS(iii)

	(i)	(ii)	(iii)
(1)	GLEYSOILS		
	(a) Eutric Gleysols	Sols a gley peu profound peu humeferes	Haplaquents, Psammaquents, Tropaquents, Andaquepts, Fragiaquepts, Haplaquepts, Tropaquepts
	(b) Calcaric Gelysols	Sols hydromorphes a redistribution du calcaire	----
	(c) Dystric Gleysols	Sols a gley peu profound	Haplaquents, Psammaquents, Tropaquents, Andaquepts, Fragiaquepts, Haplaquepts, Tropaquepts
	(d) Mollic Gleysols	Sols Humiques a gley	Haplaquolls

	(e)	Humic Gleysols	-----	Humaquepts
(2)	VERTISOLS		VERTISOLS	VERTISOLS
	(a)	Pellic Vertisols	Vertisols a drainage externe extreme nul ou redult	Pelluderts, Pellusterts, Pelloxererts
	(b)	Chromic Vetisols	Vertisols a drainage externe possible	Chromoxererts, Chromusterts, Chromuderts, Torrerts
	(i)		(ii)	(iii)
(3)	SOLONCHAKS		-----	-----
	Gleyic Solonchaks		-----	Haplaquepts
(4)	SOLONETZ		-----	-----
	Gleyic Solonetz		-----	Natraqualfs
(5)	PHAEOZEMS		-----	-----
	Gleyic Phaeozems		-----	Argiaquous
(6)	GREYZEMS		-----	-----
	Gleyic Greyzems		-----	Argiaquolls
(7)	CAMBISOLS		-----	-----
	(a)	Gleyic Cambisols	-----	Aquic Dystrochrepts Aquic Eutrochrepts
	(b)	Vertic Cambisols	Sols Bruns Eutrophes tropicaux	Vertic Tropepts
(8)	LUVISOLS		-----	-----
	(a)	Vertic Luvisols	-----	Vetic Haplozeralfs
	(b)	Gleyic Luvisols	Sols a gley Lessives	Aqualfs
(9)	PODZOLS		-----	
	Gleyic Podzols		Podzols a gley	Aquods
	(i)		(ii)	(iii)
(10)	PLANOSOLS		-----	-----
	(a)	Eutric Planosols	-----	Albaqualfs, Paleargids, Palexeralfs, Paleustalfs
	(b)	Dystric Planosols	Pseudogley	Albaquults
	(c)	Mollic Planosols	-----	Argiabolls, Mollic Albaqualfs
	(d)	Humic Planosols	-----	Albaqualfs
	(e)	Solodic Planosols	Solods	-----

(11) ACRISOLS	----	----
Gleyic Acrisols	----	Aquults

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