Online Appendix 1:

Description of the major soil types within the central eastern communal conservancies, Namibia

Nomenclature follows the revised legend of the soil map of the world (FAO-UNESCO 1988). The equivalent according to the South African Soil Taxonomic System (Soil Classification Working Group 1991) is also provided. The descriptions follow those presented in Strohbach *et al*. (2004) and are augmented with information from ICC, MAWRD & AECI (2000) and Batjes (2002).

1.1 Lithic Leptosols

South African soil taxonomic system equivalent: Mispah form

Shallow to very shallow soils underlain by a continuous rock layer. This soil type is characterised by an ochric A-horizon over fractured rocks, of which the properties are listed in Table A1.1a and Table A1.1b.

Lithic Leptosols have a low water-holding capacity due to their shallowness and gravelly nature, which also renders them with very limited agricultural potential. Their depth is restricted by continuous hard dolomite or limestone or a petro-calcic horizon. Leptosols can only be used for extensive grazing in Namibia.

1.2 Calcaric Fluvisols

South African soil taxonomic system equivalent: Oakleaf form

The calcaric Fluvisols are moderately deep to deep, dark reddish brown to dark brown, sandy to medium-textured soils that were deposited by water. Their most distinctive physical characteristics are summarised in Table A1.2a and Table A1.2b.

The upper A-horizon is covered by a thin layer of loose Aeolian sand (Figure A1.2). Fluvisols are relatively restricted to the water channels. Localised sodium accumulation may cause toxicity and water tends to pond after rains.

TABLE A1.1a: Differentiating characteristics of the lithic Leptosols.

Physical information	Description
Landform and Topography	Topography: almost flat to gently undulating Landform: isolated low dolomite or limestone ridges
Parent material	Organic sediments
Rock type	Dolomite or limestone
Surface stoniness	Sub-surfacing common dolomite or limestone rocks.

TABLE A1.1b: Differentiating characteristics of the lithic Leptosols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	0 to 5 (10)	**Moist colour:** brownish black to dark brown **Texture**: fine sand to loamy sand **pH:** slightly to highly alkaline **Drainage:** well drained **Other:** slightly calcareous, loose consistence, many to abundant fragments of quartz and sandstone and very few fine roots in the topsoil.

1.3 Arenic Fluvisols

South African soil taxonomic system equivalent: Oakleaf form

These soils are difficult to distinguish. They comprise of an orthic A-horizon over reddish dark reddish brown to reddish brown loamy sandy soils sub-horizon. Arenic Fluvisols are characterised by a A-Bw1 and Bw2 (mottled) horizons (Table A1.3a and Table A1.3b and Figure A1.3). The soils are poorly drained. A weakly developed G-horizon indicates the presence of water-logging conditions in the lower parts of the profile. The distinctive characteristics of arenic Fluvisols are summarised in Table A1.3a Table A1.3b.

1.4 Haplic Calcisols

South African soil taxonomic equivalent: Brandvlei form

Found on eroded river banks, pans and calcrete plains, these soils are moderately deep to deep overlying soft to hard calcrete. Calcisols vary markedly in depth. The haplic Calcisols are calcareous throughout. They are characterised by weakly to moderately structured, abruptly overlying calcrete gravels mixed with fine earth of the topsoil, overlying continuous hard calcrete in depressions and pans (Table A1.4a and Table A1.4b).

TABLE A1.2a: Differentiating characteristics of the calcaric Fluvisols.

Physical information	Description
Landform and Topography	Topography: flat to almost flat Landform: lowest positions of valleys, drainage lines or *omiramba*
Parent material	Alluvial deposits
Surface stoniness	None

TABLE A1.2b: Differentiating characteristics of the calcaric Fluvisols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	1 to 6	**Moist colour:** dark reddish brown to dull reddish brown to dark brown **Texture:** fine sand to loamy sand **pH:** neutral to alkaline (6.5 – 8.9) **Drainage:** well to somewhat excessively drained **Other:** contain high levels of Calcium and Magnesium, low organic content, moderate medium sub-angular blocky structure and slightly hard consistence, with very few fine roots.
Bw1	6 to 41	**Moist colour:** dark brownish grey to greyish yellowish brown **Texture:** sandy loam to loamy sand **pH:** highly alkaline (8.3 – 8.7) **Drainage:** seasonal water-logging (presence of irregular black mottling) yet low water-holding capacity in general **Other:** slightly calcareous (calcium carbonate), very low phosphorus, rich in calcium and magnesium, weak fine sub-angular blocky and soft consistence, no plant roots present.
Bw2	41 to 97	**Moist colour:** dark brown, brownish grey to reddish brown **Texture:** coarse loamy sand to sandy clay loam **pH:** slightly to strongly alkaline **Drainage:** poorly to moderately well drained **Other:** strongly calcareous, moderate coarse sub-angular blocky and slightly to extremely hard consistence, no roots found.
C Unconsolidated material	97 – 105	Not often present, if present, only weakly developed with features indicating stagnant conditions or at least water-logging

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TABLE A1.3a: Differentiating characteristics of the arenic Fluvisols.

Physical information	Description
Landform and Topography	Topography: flat to almost flat
	Landform: valley floors and interdunal streets
Parent material	Alluvial sand deposits/aeolian sand
Surface stoniness	None

TABLE A1.3b: Differentiating characteristics of the arenic Fluvisols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	1-6	**Moist colour:** dark brownish **Texture:** loamy sand **pH:** slightly acidic (6.3) **Drainage:** poorly drained **Other:** medium textured, non -calcareous, moderate medium sub-angular blocky structure, consistence slightly hard, many fine roots in the upper horizon.
Bw	7-41	**Moist colour:** greyish yellow brownish **Texture:** sandy loam **pH:** slightly acidic (6.3) **Drainage:** poorly drained **Other:** sandy loam textured sub-horizon when moist, slightly-calcareous, weak fine sub-angular blocky structure, consistence soft.
G	42-97	**Moist colour:** Dark brownish **Texture:** sandy clay loam **pH:** slightly acidic (6.1) **Drainage:** Seasonal water-logging **Other:** moderate coarse sub-angular blocky structure, slightly hard to hard consistence or slightly compacted layer with few fine yellowish black mottles.

There is evidence of surface sealing on the topsoil. These soils are moderately well drained.

1.5 Mollic Leptosols

South African soil taxonomic equivalent: Mispah form

Mollic Leptosols are shallow to very shallow soils underlain by hard petro-calcic horizons. This soil type is characterised as an ochric A-horizon, of which the properties are listed in Table A1.5a and Table A1.5b.

Mollic Leptosols have a low water-holding capacity due to their shallowness and gravelly nature, which also renders them very limited in agricultural potential. Their depth is restricted by a petro-calcic horizon. The soils are highly fertile but their usage is restricted by their shallow and rocky nature.

1.6 Haplic Arenosols

South African soil taxonomic equivalent: Hutton form

Haplic Arenosols are deep, leached and nutrient-poor soils. These soils comprise of an ochric A-horizon and a B-horizon of pure sand showing no signs of structure development. Arenosols are well drained, non-calcareous and vary in colour from red to yellow-brown orange. The prominent characteristics of haplic Arenosols are summarised in Table A1.6a and Table A1.6b and Figure 1.6.

Overall, the haplic Arenosols show very weak to weak horizon development (Figure A1.6). The sands are generally fine grained or loamy fine sand with slight clay content. Occasionally the sub-horizons have a sandy loam texture. Nutrient status and water-holding capacity is low. These soils show few to no signs of erosion.

TABLE A1.4a: Differentiating characteristics of the haplic Calcisols.

Physical information	Description
Landform and Topography	Topography: almost flat to gently undulating
	Landforms: valleys, pans and interdunal depressions
Parent material	In situ weathering processes
Surface stoniness	None

TABLE A1.4b: Differentiating characteristics of the haplic Calcisols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	1-23	**Moist colour:** brownish black **Texture:** sandy clay loam **pH:** slightly acidic (6.1) **Drainage:** well drained **Other:** slightly calcareous, very weak fine sub-angular blocky with soft consistence, common to many fine roots in the upper horizon.
Bwck1	23-47	**Moist colour:** brownish black **Texture:** sandy loam to sandy clay loam **pH:** neutral (7.1) **Drainage:** moderately well drained **Other:** slightly calcareous, very weak structure, many fine to moderate irregular petro-calcic gravel's, few fine roots and few medium roots.
Bwck2	47-73	**Moist colour:** brownish black **Texture:** sandy loam to sandy clay loam **pH:** alkaline (8.3) **Drainage:** moderately well to poorly drained **Other:** strongly calcareous, very few fine roots.
C	73-76	Powdery to hard calcrete or petro-calcic horizon

TABLE A1.5a: Differentiating characteristics of the molic Leptosols.

Physical information	Description
Landform and Topography	Topography: flat to gently undulating
	Landform: calcrete plains
Parent material	Organic sediments
Rock type	Dolomite/Limestone and calcrete
Surface stoniness	Many to common sub-rounded calcrete pebbles on the surface.

TABLE A1.5b: Differentiating characteristics of the molic Leptosols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	0 to 5 (10)	**Moist colour:** brownish black to dark brown **Texture:** fine sand to loamy sand **pH:** slightly to highly alkaline **Drainage:** well drained **Other:** highly calcareous, loose consistence, many to abundant fragments of limestone and abundant fine roots in the topsoil.

1.7 Ferralic Arenosols

South African soil taxonomic equivalent: Hutton form

These are the very deep reddish brown to bright reddish brown sandy soils. Their most distinctive characteristics are summarised in Table A1.7a and Table A1.7b.

There is some evidence of slight erosion in the form of pedestals. Biogenic crusts are common in these soils. Ferralic Arenosols have a poor capacity to retain nutrients and moisture. Horizon development is absent to very weak, consisting of an ochric A-horizon and a weathered B-horizon (sometimes with sub-

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TABLE A1.6a: Differentiating characteristics of haplic Arenosols.

Physical information	Description
Landform and Topography	Topography: flat to almost flat topography Landform: Kalahari sand plain
Parent material	Aeolian sand
Surface stoniness	None

TABLE A1.6b: Differentiating characteristics of haplic Arenosols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	1-12	**Moist colour:** dull yellowish brown to bright yellowish brown **Texture:** sand **pH:** acidic to slightly acidic (5.3 – 6.3) **Drainage:** excessively well drained **Other:** carbonate free, loose to very weak and fine to medium sub-angular blocky structure, consistence soft, very low organic content, very few fine roots in the A horizon.
Bw1	12-63	**Moist colour:** dull yellowish brown to dark brown to bright brown **Texture:** sand to loamy sand **pH:** slightly acidic (5.9 – 6.7) **Drainage:** moderately well to well drained. **Other:** very low to low soluble salts, carbonate free, phosphate low to absent, loose structure, many fine roots and few coarse roots which extend into the Bw2 horizon
Bw2	63-133	**Moist colour:** dull yellowish brown to grey yellowish brown to bright brown **Texture:** sand with slight clay content **pH:** slightly acidic **Drainage:** excessively well drained **Other:** carbonate free, loose to weak and fine to medium sub-angular blocky structure, consistence slightly hard when dry, very few to few coarse roots in the Bw2 horizon.

TABLE A1.7a: Differentiating characteristics of the ferralic Arenosols.

Physical information	Description
Landform and Topography	Topography: flat to undulating to rolling topography Landforms: dunes, sand plains, sand ridges
Parent material	Aeolian sand
Surface stoniness	None

TABLE A1.7b: Differentiating characteristics of the ferralic Arenosols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	1 to 23	**Moist colour:** reddish brown to dark reddish brown **Texture:** sand **pH:** acidic (5.3 – 6) **Drainage:** excessively well drained **Other:** no free salts and carbonates, organic content very low, consistence soft, many fine roots in the upper horizon.
Bw1	23 to 61	**Moist colour:** dark reddish brown to reddish brown **Texture:** sand **pH:** acidic (5.2 – 6) **Drainage:** moderately well to well drained **Other:** no calcium carbonate, very few to few black gleying mottles indicating limited water-logging, very low to low soluble salts, phosphorus absent or extremely low, low cation exchange capacity, consistence soft, few fine roots and few medium roots.
Bw2	61-120	**Moist colour**: reddish brown to bright reddish brown **Texture:** coarse sand **pH:** slightly acidic **Drainage:** excessively well drained **Other:** non-calcareous, structure loose to weak and fine to medium sub-angular blocky, consistence soft to slightly hard, few fine roots and few medium roots.

horizons) (Figure A1.7). Occasionally slight sheet erosion has been observed, while wind erosion is common.

1.8 Petric Calcisols

South African soil taxonomic equivalent: Prieska form

Calcisols vary in depth. These are calcareous soils that overlie a hard petrocalcic horizon of C-horizon at a depth of 45 cm or less. Their most prominent characteristics are summarised in Table A1.8a and Table A1.8b.

The high clay in the ochric A-horizon tends to become compacted when dry. Fine materials are easily blown away by water and wind which result in the exposed hard calcrete at the soil surface. The petro-calcic horizon becomes extremely hard when dry, forming a barrier to coarse and medium roots. Only fine roots can penetrate between the rock spaces and take advantage of the (relative to the study area) more favourable moisture-retention properties. Most importantly, in the sandy *omiramba* this is reflected by the presence of a dense grass layer and sparse to absent tree and shrub layer. The establishment of crops on these soils will only be possible with costly irrigation and frequent application of nutrients such as nitrogen and phosphorus, but also micronutrients such as iron and zinc. Overall these soils are characterised by especially their A and C horizons (Figure A1.8).

TABLE A1.8a: Typical characteristics of the *petric* Calcisols.

Physical information	Description
Landform and Topography	Topography: slightly sloping to undulating topography Landforms: sand plains, *omiramba,* interdunal streets, pans
Parent material	In situ weathering/aeolian sand
Surface stoniness	None
Salinity/ Alkalinity	Saline
Crust formation	Slightly

TABLE A1.8b: Typical characteristics of the *petric* Calcisols.

Generic Horizon	Horizon data and information	
	Average horizon depth range (cm)	*Description of the horizons*
A	1 to 4	**Moist colour:** dark brown to brownish black **Texture:** loamy sand **pH:** acidic (5.8 – 6.1) **Drainage:** poorly to moderately well drained **Other:** slightly calcareous, weak fine sub-angular blocky, consistence soft, organic content is very low, many fine roots in the A-horizon.
Bwck	4 to 47	**Moist colour:** dark brown to dull reddish brown **Texture:** sandy to loamy sand or sandy clay loam **pH:** slightly acidic to alkaline (6 – 8.7) **Drainage:** poorly drained **Other:** Moderately calcareous, weak fine sub-angular blocky, few medium to coarse roots in the Bw1 horizon
Bw2	47 to 89	**Moist colour:** dark brown **Texture:** loamy sand to sandy loam **pH:** slightly alkaline **Drainage:** poorly drained **Other:** slightly calcareous, moderately medium sub-angular blocky, very few coarse roots in the Bw2 horizon, slightly cemented with calcium carbonate
C	89 to120	Strongly calcareous petro-calcic horizon, either with powdery or hard calcrete or the accumulation of secondary calcium

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Figures

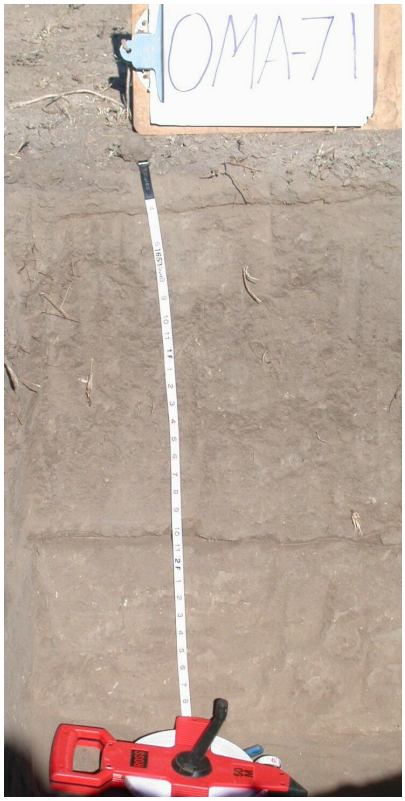

FIGURE A1.2: Typical calcaric Fluvisol.

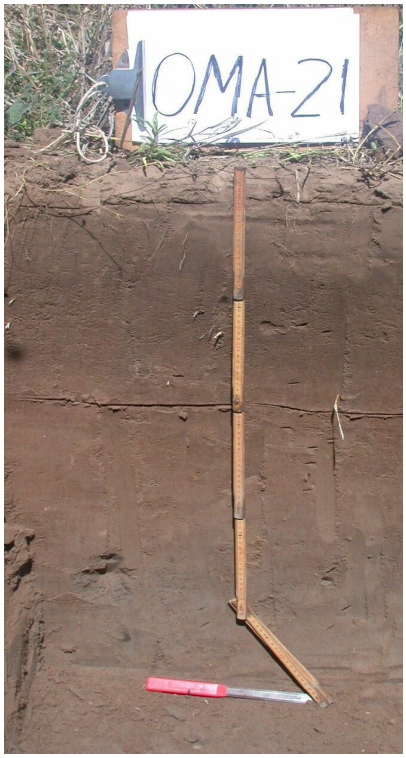

FIGURE A1.3: An arenic Fluvisol consists of an ochric A-horizon and a dark brown Bw1-horizon over weakly wet or gleyed clay-rich material (Bw2-horizon).

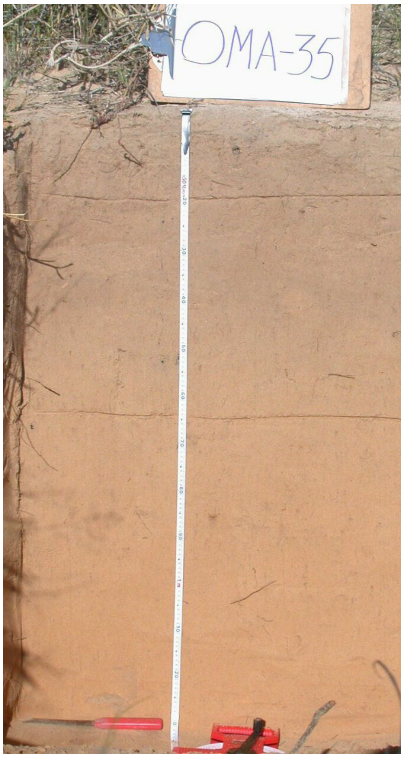

FIGURE A1.6: Typical profile of a haplic Arenosol showing the ochric A-horizon overlying a dark brown Bw1-horizon, followed by a leached Bw2-horizon.

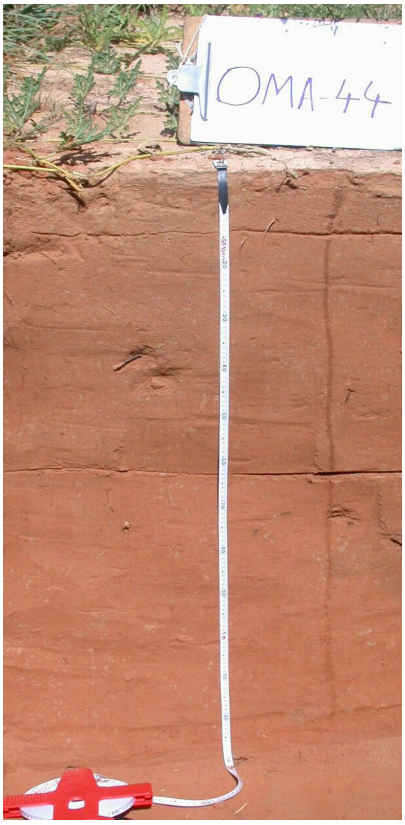

FIGURE A1.7: Typical profile of a ferralic Arenosol, indicating the different horizons.

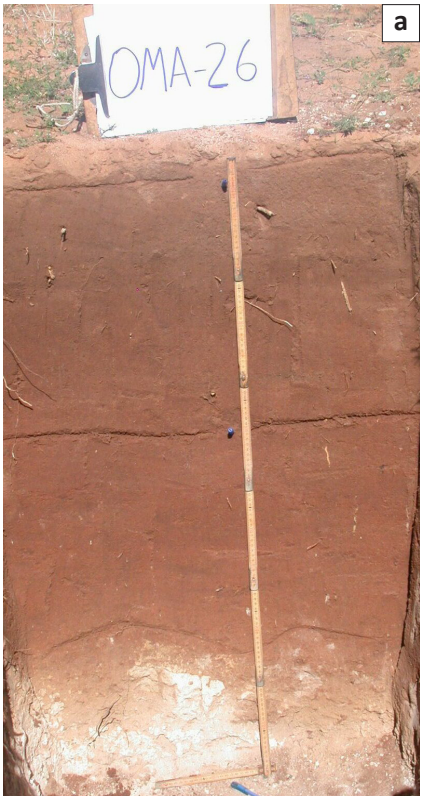

FIGURE A1.8: (a) A typical petric Calcisol, consisting of an ochric A-horizon over a moderately deep B-horizon overlying soft or hard calcrete or petrocalcic horizon (white layer at the bottom). (b) An extraordinarily shallow example of a petric Calcisol, as often found in the calcrete pans.

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