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Climate, relief, bedrock and substrate – main factors for the soil formation in arid regions

The research areas of ACACIA are mainly located in the subtropical and tropical deserts. However, towards the equator they partly extend into the ecozone (cf. Schultz 2005) of the seasonal tropics with summer rain (thorn savanna) and towards the poles into the Mediterranean-type subtropics (grass and shrub steppe) with winter rain. The climatic conditions of these arid to semiarid regions with frequently high diurnal variations in temperature are crucial factors for the weathering and soil formation (pedogenesis). Due to periodic or permanent water shortage, plant growth and therefore also the formation of humus is highly limited. Consequently, the aeolian processes (deflation, sedimentation) and the recycling of soluble salts play a major role. Additionally, the pedogenesis are considerably affected by the properties of the source rock (e.g. loose or hard, rich or poor in carbonate) and by the relief. On steep slopes and in high altitudes, for example, only shallow soils or even bare bedrocks are typical. In contrast, in lower parts of the relief, aggradation of sediments is common and groundwater as well as a surplus of water from the surrounding slopes leads to an accumulation of salts.

A hypsometric map (Fig. 2) shows the topographical differences of Africa and the two wider ACACIA research foci (cf. Fig. 1). In the northeast of the continent areas with altitudes over 750 m a.s.l. are very limited. In contrast, southern Africa mainly lies above 1,000 m a.s.l.

Regarding the topographic variations (relief energy or surface roughness), there are also conspicuous differences. Extensive plains prevail in the northeastern focus. Steep slopes with a higher relief energy are concentrated on single mountains, mountain ranges (e.g. Gilf Kebir, Ouenat, Ennedi, see satellite images, pages 215-235) or escarpments (e.g. in the surrounding of the Egyptian oasis). In the southwest the relief energy is generally higher, particularly in the range of the Great Escarpment but also in the mountainous parts of the Kunene Region. Taking into consideration that the precipitation values in the southwestern focus are generally higher (Bubenzer & Ritter, this volume), higher amounts of fluvial erosion are likely here. In the northeastern focus, on the other hand, aeolian processes are more effective, due to the extremer aridity and the mostly flat terrain.

The conditions outlined above are reflected in the geographical extension of soil groups of the "World Reference Base of Soils Resources (WRB)" (after FAO 1998, cf. Zech & Hintermaier-Erhard 2002) in the two research foci under consideration (Fig. 1):

- Arenosols accommodate the soils that develop in relatively coarse and unconsolidated material, particularly in dune sand but also in sandstone, quartzite, and granite. They cover the largest areas in both research regions (e.g. Great Sand Sea, Selima Sandsheet in the NE, Namib and Kalahari in the SW).
- Calcisols develop especially in colluvial, lacustrine, aeolian or alluvial sediments rich in calcium carbonates. Many Calcisols occur together with Solonchaks. In the NE they are common in the Tertiary Limestones (e.g. in the Western Desert of Egypt). In the SW they are widespread

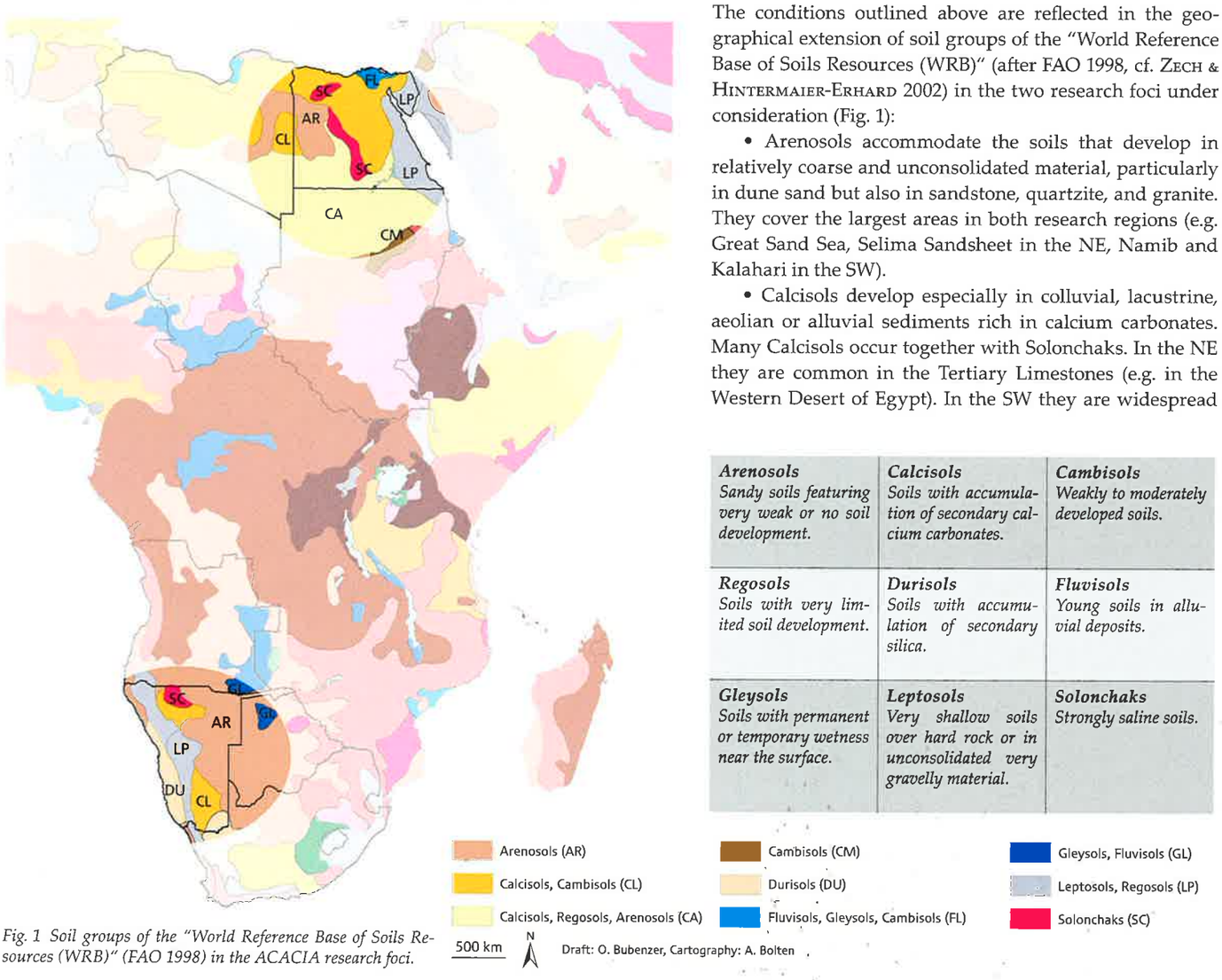

Fig. 1 Soil groups of the "World Reference Base of Soils Resources (WRB)" (FAO 1998) in the ACACIA research foci.

Arenosols *Sandy soils featuring very weak or no soil development.*	***Calcisols*** *Soils with accumulation of secondary calcium carbonates.*	***Cambisols*** *Weakly to moderately developed soils.*
Regosols *Soils with very limited soil development.*	***Durisols*** *Soils with accumulation of secondary silica.*	***Fluvisols*** *Young soils in alluvial deposits.*
Gleysols *Soils with permanent or temporary wetness near the surface.*	***Leptosols*** *Very shallow soils over hard rock or in unconsolidated very gravelly material.*	***Solonchaks*** *Strongly saline soils.*

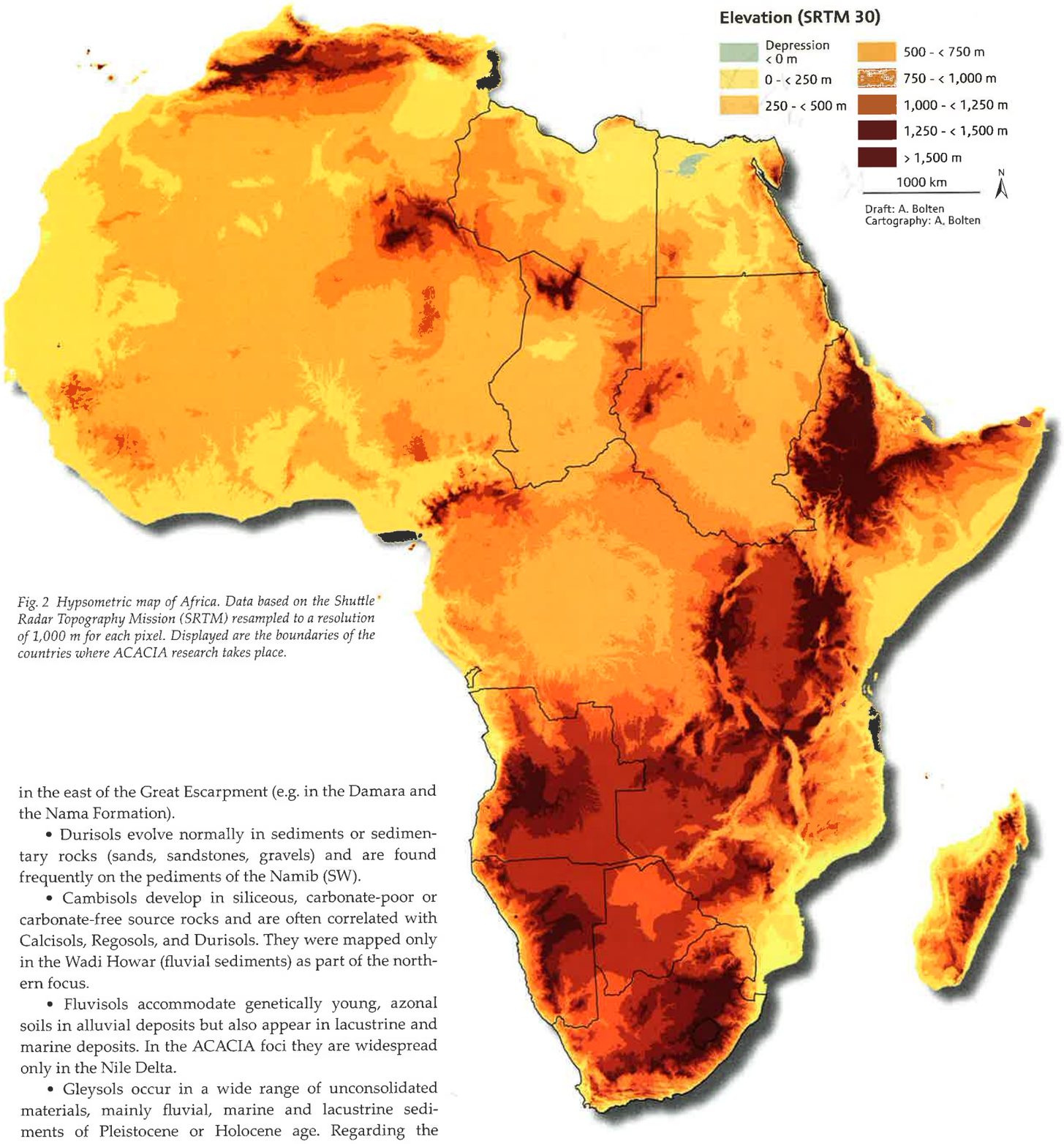

Fig. 2 Hypsometric map of Africa. Data based on the Shuttle Radar Topography Mission (SRTM) resampled to a resolution of 1,000 m for each pixel. Displayed are the boundaries of the countries where ACACIA research takes place.

in the east of the Great Escarpment (e.g. in the Damara and the Nama Formation).

- Durisols evolve normally in sediments or sedimentary rocks (sands, sandstones, gravels) and are found frequently on the pediments of the Namib (SW).
- Cambisols develop in siliceous, carbonate-poor or carbonate-free source rocks and are often correlated with Calcisols, Regosols, and Durisols. They were mapped only in the Wadi Howar (fluvial sediments) as part of the northern focus.
- Fluvisols accommodate genetically young, azonal soils in alluvial deposits but also appear in lacustrine and marine deposits. In the ACACIA foci they are widespread only in the Nile Delta.
- Gleysols occur in a wide range of unconsolidated materials, mainly fluvial, marine and lacustrine sediments of Pleistocene or Holocene age. Regarding the ACACIA research regions, they cover larger areas only in the Zambezi catchment and in the Okavango Basin.
- Leptosols are azonal soils and particularly common in mountainous regions and in stony deserts. They are frequent on slopes with continuous erosion and appear together with Regosols. In the NE, for example, they are widespread in the Egyptian Eastern Desert, in the Tibesti, and in the Ennedi. In the SW they are found in the mountainous areas of the Great Escarpment.
- Regosols are weakly developed soils in unconsolidated fine to middle grained material. They often occur together with Leptosols and Calcisols. In the research foci they can be found in basins and in the transition zones from sandy to stony deserts.
- Solonchaks evolve in unconsolidated material (sandy, silty, clayey), e.g. in basins and depressions (sebchas, playas). They are widespread in areas where ascending groundwater reaches the soil and are prevalent in all arid and hyperarid research areas of ACACIA. However, larger connected areas with Solonchaks in the NE are restricted to the low lying depressions and basins (e.g. the Qattara Depression and the oasis of the Western Desert of Egypt). In the SW they occur in the Etosha Pan.