Scrub invasion of Open Grasslands: Soil Moisture Balance

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Open grasslands as a pure physiognomic type have no trees or shrubs emergent above the mature grass canopy level. Where woody plants grow out above the grass canopy level open grassland becomes a savanna or wooded grassland system. Certain grasslands, as on the southern Mozambique Coastal Plain sands, contain colonies of dwarf shrubs within the mature grass canopy which are only exposed by fire or overgrazing. There are desert (deep sands/ hardpan), coastal (deep sands/high watertable), and many kinds of impeded drainage open grasslands (Tinley 1977, 1982; Fey 2010; Pringle et al. 2013). Only varieties of the latter types from across Southern Africa are used here as examples. These grasslands are supported by soils with poor subsoil drainage that undergo extreme seasonal contrasts in soil moisture – from waterlogged to edaphic drought. These edaphic controls reflect both the soil types and terrain drainage factors.

Examples include all duplex, plinthic, vertic and gley soils, the hydromorphic vleis (dambos) and floodplains, and heavy clays such as those that develop on basalt and dolerite. For example, the Highveld, East Cape and Natal podzol-like soils of Van der Merwe (1962), now classified as plinthic in revised terminology (Fey 2010). In the rainy growing season these soils become waterlogged due to the clay or gley subsoil that is impermeable to through flow of moisture and to plant root penetration. In the dry season this perched watertable condition is followed by extreme soil desiccation often with cracks in the clay subsoils. These edaphic conditions preclude woody seedling survival at both extremes, hence the occurrence of grasslands without trees. Soil moisture balance (SMB) is the amount of moisture required to support and maintain a particular kind of plant community in a state of dynamic equilibrium or balance. Anything that shifts this balance towards drier or wetter conditions entrains changes in the plant cover's physiognomy and species composition as adjustments to the altered edaphic condition develop. In regard to open grasslands on poor draining soils, any factor such as erosion that changes the moisture balance condition towards a better drained aerobic state enables woody seedlings to become established. SMB is also of course a fundamental determinant not only of plant growth and their patterns of occurrence, but also of phenology at all scales.

For example at the macroscale across the subcontinent tropics from Namibia to Mozambique (between 18 and 20 degrees south latitude) is the phenomenon of the pre-rain woody plant spring flowering beginning in the last week of July, and the grass spring growth delayed until the first summer rains in November due to edaphic drought in their root zone (Tinley 1977).

Several examples serve to illustrate how changes in the soil moisture balance of impeded drainage soils is affected by site or area disturbances. These changes result in the development of increasing successional complexity in habitat form and structure, biotic composition, and herbivore carrying capacity. Depending from which side of the Highveld Grassland Region invasive woody succession plants are coming – these can be of karroid shrubland, arid savanna, savanna woodland, thickets, or forest in the Drakensberg.

(1) Rock outcrops: Rainwater is shed and follows the underground rock surface bypassing the impervious gley horizon. This enables seeds to become established as their roots also follow the rock surface past the moisture barrier (as shown from soil trenches).

(2) Fence posts: Something as simple as belting a fence post into or through the gley horizon will, similarly to the above example, enable seedlings to become established, their roots closely following the pole into the subsoil. Bird mediated bushclumps around fence-posts in the Eastern Cape for example.

(3) Edaphic drought: Edaphic drought from one, or a combination of factors, including fire intensity and frequency, and/or overgrazing, results in a shorter and more widely spaced grass cover increasing rain run-off loss and hence soil profile dehydration. The more obvious factors are rill and gully erosion and the more subtle are overgrazing, excessive annual fires, or ungrazed or unburnt moribund grass cover, resulting in topsoil loss and pedestalling of grass tufts. Edaphic drought from all these factors serve to the advantage of scrub seed establishment. The drying out is also too often initiated or exacerbated by erosion gutters caused by stock or game paths, roads, tracks, and fencelines. Decreased waterlogging with cracks in the drying clay during the growing season is exploited by acacia seedling roots that penetrate through the subsoil horizon and enhance free drainage further. Once established, each acacia, like the fence-posts, serve as perch sites for bird dispersal of berry plants that often develop into thickets. In the eastern Cape and KwaZulu Natal the grasslands have in many areas been transformed by acacia scrub invasion whose seeds are dispersed by stock and game (*Acacia karroo* in the Eastern Cape; *A. nilotica* and *A. tortilis* in middle and lowveld KwaZulu Natal, and *A. sieberiana* in upland Natal).

(4) Planting trees for gardens or plantations: the planting of tree saplings 50 to 100 cm in height typically requires soil pits to be dug which exposes the impeding horizon, or breaks through it, providing free drainage and aerating the soil profile.

(5) Wetlands and vlei drainage: Climate change, over-abstraction and pollution are seen to be the greatest threats to wetlands and run-on habitats of all kinds (e.g. Rochier et al. 2001; Neke & du Plessis 2004). However, the continually overlooked primary threat to vlei grasslands and wetlands is the breaching of their ponding sills by upstream migrating gully erosion that is worsened with every rain (Tinley & Pringle 2014). Initially a subtle and insidious process in terrain of low relief, the slightest drainage incision such as a cattle path can initiate the unplugging of wetlands and their replacement by scrub, resulting in the ongoing haemorrhaging of soil moisture across landscapes. To re-instate vlei grasslands and rehydrate the landscape the first step is to re-establish the ponding sills. The second step is to review the run-off condition of the catchment to identify where simple yet effective rainwater harvesting and spreading interventions can be established to replenish soil moisture (Tinley & Pringle 2014). In aridlands run-on surfaces such as pans, outwash fans, vlei drainage and seasonally or irregularly waterlogged grasslands are vitally important habitats. In Namibia for example these are widespread inland down the length of the country, all liable to loss by donga breaching (Pringle et al. 2013).

(6) Mozambique vertisol floodplain grasslands (Tinley 1977): Where the ponding sill of a Rift Valley lake surrounded by floodplain grasslands has been breached by drainage incision these open grasslands are invaded from the savanna margins by fever trees (*Acacia xanthophloea*). This scrub occurs in even aged/size bands related to the still-stand periods of the dropping flood level reach, with smallest most recent scrub closest to the contemporary standing water level and oldest/largest mature woodlands up the faint slope. Where these base-rich vertisols are no longer flooded and have become converted to aridosols they are colonized on the raised rims of the gilgai microbasins by mopane, *Colophospermum mopane*.

(7) Basalt and Dolerite Clay Open Grasslands: Like the duplex gleys and tropical vertisols, these clays also exhibit seasonal extremes of soil moisture. The Drakensberg heavy clays on the steep basal slopes have a granular clayey topsoil over a heavier clay subsoil which becomes massive and plastic when wet. In contrast, during the winter dry season, the profile becomes desiccated and compact, any moisture remaining is tightly bound and mostly unavailable to plants. Hence, the woody plant distribution pattern is confined to aerobic, moist sites provided by rock outcrops, or where slumping and incision of slopes occur, or at sinkholes formed by pipe drainage. This vegetation pattern is reinforced by grassfires pruning back the woody plants in the dry season. The clays of the steep basal slopes do not only undergo extremes of soil moisture, but are subject to gravity-induced slip scar formation that relates to their plastic condition when wet. The crescent shaped scars, aligned transverse to slope, are enlarged in winter by frost heaving as the moisture holding subsoil clay is exposed at the scar surface.

(8) Frost & Fire: On the Highveld, as exemplified by the Free State, it is the valleys that are subjected to the lowest winter frost temperatures due to temperature-inversion and cold air drainage. However, this is where the densest woody growth occurs along the incised stream courses that unplugged and replaced the vlei grassland systems. The early ideas that frost and/or fire are the cause of treeless grasslands in the Highveld, are negated by the fact that frost and fire occur in the dry season dormant period, and by the proven evidence of the edaphic controls ("…fire acts mainly in widening the boundaries of open grasslands formed by other causes…" (Michelmore 1939). In Etosha and the Okavango, shrub coppice ("dwarf") mopane occur on the slightly lower ground of unplugged dense grass drainage flats where they are burnt back by black frosts and fire. Abutting such flats on interfluves, that are only some 80 cm higher than the floor of the flats, are tall mopane trees in woodland form with sparse grasses that are rarely burnt.

In Conclusion

These examples of changes in SMB do not of course occur in isolation but within drainage geoecosystem units and tributary sub-unit compartments bound by their watershed divides. Modification of terrain by erosion in one part of a drainage system can eventually effect spreading changes in SMB and hence of the biotic make-up of the entire system both upstream and downstream. Unless they are stabilised these geomorphic processes result in the ongoing demise of upslope wetlands (and topsoil loss in Highveld grasslands for example) enabling the encroachment of woody plants from many sides. Unless re-plugged to restore seasonally high moisture edaphic conditions, most efforts to counter scrub encroachment such as burning, heavy goat browsing, or chemicals, are unlikely to be long lasting solutions. The field evidence indicates that soil moisture balance is the most significant edaphic feature controlling landscape change as it overrides or influences all other factors. This evidence has been derived from nearly six decades of field ecology investigations across Southern Africa, Saudi Arabia and Western Australia with soil profile scrutiny everywhere with the aid of spade, pick and auger.

Typical even-aged patterns of scrub invasion of grassland in response to the baring and drying of the soil, by a vehicle track, fence-line and cattle pad, also on overgrazed paddock at right.

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Invasive scrub initials are one of the first signs that floodplain grasslands are in a drying trend from the breaching (unplugging) of their overflow outlets. This example is of the gilgai soil microrelief pattern. The scrub pioneers are confined to colonising the drier micro-ridges between the micro-basins.