3 Coastal Dunes in the Tropics and Temperate Regions: Location, Formation, Morphology and Vegetation Processes

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3.1 Introduction

The following is an attempt to examine the differences between coastal dunes occurring in the tropics and those mid-latitude (mostly temperate) areas outside the tropics but principally within 50°N and 50°S. The tropics lie between 23.5°S and 23.5°N of the equator bounded by the Tropics of Cancer and Capricorn.

3.2 Climatic Conditions in the Tropics

Climatic conditions can act as major controls on whether aeolian dunes are able to form, the types of coastal dunes that form and dune-field stabilsation processes, as well as the prevailing vegetation biomes, vegetation growth rates and the structural types present. Given this, the following briefly outlines the climatic regions and the associated terrestrial biomes which occur in the tropics.

Within the latitudes of 23.5°N and S of the equator, and near the coast, there are two principal climatic regions (following the Köppen-Geiger classification system), namely, tropical climates and dry, arid/semiarid climates (Fig. 3.1). Mesothermal climates (particularly humid subtropical climates) are also present but occur to a much lesser extent (Christopherson 2000). Within the tropical climatic regions, tropical rain forest and tropical monsoon climate types principally occur on the east coasts of South America, Central America, on the west coast of Africa between around 4°S and 10°N of the equator, and much of SE Asia and in South Asia, the west coast of India and the coast of Bangladesh. These regions are dominated by the equatorial and tropical rain forest terres-

Ecological Studies, Vol. 171
M.L. Martínez, N.P. Psuty (Eds.)
Coastal Dunes, Ecology and Conservation

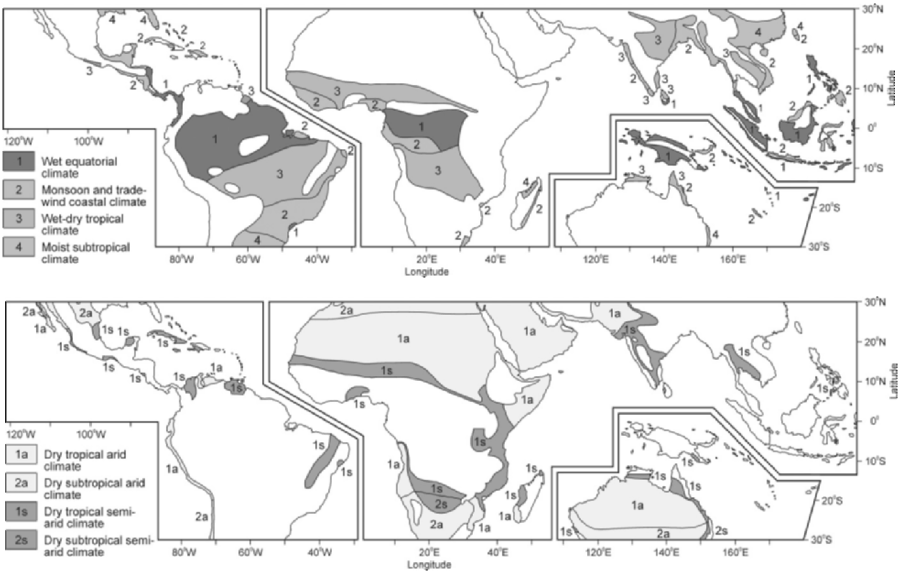

Fig. 3.1. World maps indicating the main regions of wet to moist and monsoon and trade wind tropical and subtropical climatic regions (1a), and dry arid to semi-arid tropical and subtropical climatic regions. (Modified from Strahler and Strahler 1997)

trial biome. Tropical savannah climate regions principally occur in central Brasil (along with seasonal forest and scrub), the west coast of Central America and Mexico, the east coast of Africa below the equator, and the east coast of India and northern Australia. Most of these regions are dominated by tropical savannah biome except for most of the west coast of Central America and Mexico (predominantly warm desert and semi-desert biome) and northern Australia (tropical seasonal forest and scrub biome). Dry arid and semiarid climates dominate the climate of west coast South America, the African west coast (desert and tropical savannah biome, excluding the above ~4–10° west coast region) and east coast north of the equator, the Arabian Peninsula, and the west coast of Australia. Humid subtropical climate types occur between around 18°S and the Tropic of Capricorn in eastern Australia (tropical rain forest biome) and to a minor extent near the Tropic's in Brazil (equatorial and tropical rain forest biome) and China (broadleaf and mixed forest biome) (Christopherson 2000).

3.3 The Location of Coastal Dunes in the Tropics

In general, there are very few dune fields in SE Asia. Verstappen (1957) describes a small transgressive dune field at Parangtritis, Java, Indonesia. It is the largest dune field in Indonesia with dunes reaching up to 15 m . It is fronted by a high energy intermediate to dissipative surf zone (Hesp, pers. observ.) and while Verstappen (1957) and Bird (1985) argue that it was initiated by human disturbance, the local conditions (coastline orientation to southeasterly dry monsoon winds, a winter dry season, high energy surf zone, and a sand supply) indicate that it may be a natural occurrence modified by human pressures (Hardjosuwarno and Hadisumarno 1993). Two other significant dune fields with dunes up to 20 m in height occur at Pasirbesi and Puger in Java (Hardjosuwarno and Hadisumarno 1993).

Very few sand dunes are present in Thailand (Pitman 1985). In some areas beach ridges may have small aeolian caps. There are no dunes in Singapore, and, as noted below, there is very limited dune development in Malaysia (Swan 1971; Teh 1985, 1992).

There is only one area of significant dune-field development in the Philippines (Fig. 3.2). A large parabolic dune field (the LaPaz dune field) occurs on the northwest coast above 17° N (Alex Pataray, National Institute of Geological Sciences, University of the Philippines, pers. comm.). Parts of the coast of Vietnam from the Bay of Along (~19° N) to Cape Vung Tau (also called Cape Saint-Jacques; 10° N) in the south also has significant transgressive dune

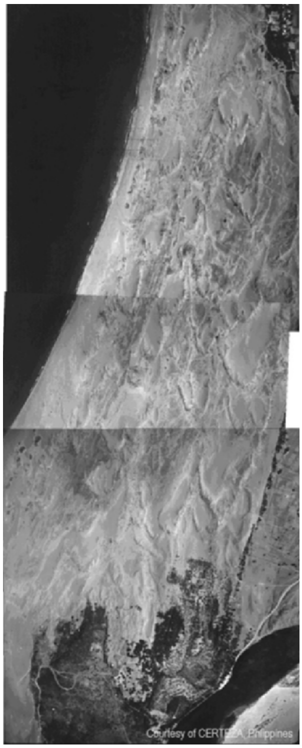

Fig. 3.2. Photo-mosaic of the parabolic dune field on the western coast of Ilococ Norte, northern Luzon, Philippines, located at 18°13′–18°15′N, 120°31′–120°34′E. The approximate scale of the central photograph is 1.5 km across the centre of the photograph from the shoreline to the edge of the photograph. (Photo courtesy of Alex Pataray)

fields (Lam Cong Dinh 1998), although local information suggests that these dunes were formerly vegetated (and most probably a different dune type) prior to defoliation during the Vietnam War.

Extensive parabolic and transgressive dune fields occur in NE Queensland and the Northern Territory in both tropical monsoon and savannah climates (Pye 1983a–c; Lees et al. 1990; Shulmeister and Lees 1992; Shulmeister et al. 1993; Swan 1979b). Massive transgressive dune fields and very large foredune plains have developed all along the tropical coast of Brazil (De Lacerda et al. 1993; Dillenburg et al. 2000) and, in fact, some of the largest dunes and dune fields are within approximately 2–3° of the equator (Maia et al. 1999; Fig. 3.3).

Small dune fields occur on the tropical West African coast (Lee 1993), and Cuba (Borhidi 1993). The Galapagos Islands are typified by a single foredune in most cases (van der Werff and Adsersen 1993). Small foredunes and relict foredunes up to 10 m in height occur in parts of the West Indies (Stoffers 1993; Gooding 1947; Davidson-Arnott, pers. comm.), and small foredunes and relict foredunes occur at Cox's Bazaar in Bangladesh (Alam et al. 1999). Dunes are also found in Hawaii (Stearns 1970; Richmond and Mueller-Dombois 1972), the Seychelles (Piggott 1968), Ghana (Talbot 1981), west and east coast India (Kunte 1995; Sanjeevi 1996) and Christmas Island (Valencia 1977).

Coastal dunes of various types (foredunes, foredune plains, transgressive dune fields) occur along 300 km of the Sri Lanka coast lying within 10° of the equator (Swan 1979a). Swan notes that the best dune development occurs in areas of strong, persistent onshore winds and long dry season.

One dune field comprising very large parabolic dunes occurs in Fiji at the mouth of the Sigatoka River where the river effluent and energy do not allow the coral reef to form. Two small areas of dunes also occur on Yasawa and Vatulele (Fiji) (Dickinson 1968; Nunn 1990).

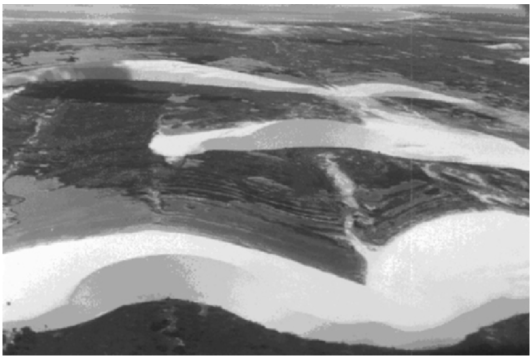

Fig. 3.3. Large (up to 50 m high) barchanoidal transverse dunes near Jericoacoara, Ceará, NE Brasil (3°S). Inter-dune deflations plains are rainwater flooded in the short wet season and 'cuspate vegetation marks' are formed by vegetation growth along the upwind margins of the dunes. Trailing ridges are formed by vegetation growth on the outside margins of the dune wings and horns (Photograph L.P. Maia)

Extensive vegetated and active transgressive dune fields occur on the Gulf coast of Mexico in latitudes 19–21°N. The dune fields comprise several phases and the active dunes are characterised by a variety of dune types including barchanoidal, transverse, aklé and large star dunes (see below).

There are many coastal dune fields in the arid and semi-arid tropics, including extensive ones in Namibia (Penrith 1993; Lancaster 1989; Hesp and Hastings 1998; Boucher and Le Roux 1993), the west coast Mexico extending from north of the Tropic to just below it (particularly Baja California, Mexico; Fryberger et al. 1990; Johnson 1993; Murillo de Nava and Gorsline 2000), Peru (Finkel 1969), Chile (Araya-Vergara 1986), NW Western Australia from the Tropic of Capricorn to approximately Cape Baskerville in Dampier Land (Hesp and Chape 1984). Small coastal dune fields (often just small foredunes, nebkha and relict foredunes) occur on the Asian Red Sea coast (Zahran 1993), in Somalia (Pignatti et al. 1993), the UAE, Saudi Arabia (Gheith and Abou Ouf 1996), Kuwait (Zahran 1993), Oman (Ghazanfar 1999), western Sahara, Mauritania (Hemminga and Nieuwenhuize 1990; Kocurek et al. 1991) and Senegal. Some of these dune fields lie along the edge of desert dune fields and in some cases are either barely distinguishable from the desert dunes (e.g. Namibia; Chile–Peru; Baja California, Mexico; Oman) or the desert extends to the coast from inland areas (e.g. Mauratania; the Rub' al Khali – Jafura sand sea in Saudi Arabia extending from within the tropics to the adjacent coast outside the tropics (Anton and Vincent 1986).

The presence of dunes and dune fields as listed above largely debunks the notion that sand dunes were either very poorly developed, or largely absent in the "humid tropics" (e.g. Jennings 1964; Pye 1983 c).

3.4 Are There Differences Between Tropical and Temperate Coastal Dunes Types and Processes?

The following sections address the question of whether there are, in fact, any real differences between dunes that develop in the tropics versus dunes that evolve outside the tropics. Since few comparative studies have been carried out, the discussion remains tentative. It should also be borne in mind that coastal dunes existing and developing across the actual Tropics of Capricorn and Cancer (i.e. around 20–25°N/S) are unlikely to be different from those dunes at 23.5° (N/S), and therefore probably have little regard for the tropic lines drawn on world maps!

3.5 Foredunes

Foredunes may be classified into two types, incipient and established foredunes. Incipient foredunes are new, or developing foredunes forming within pioneer plant communities. They may be formed by sand deposition within discrete or relatively discrete clumps of vegetation, or individual plants, or driftwood, flotsam etc. (types 1a and 1b of Hesp 1989), forming shadow dunes, vegetation mounds and nebkha. These may form at various locations ranging from the immediate backshore to back-barrier flats (Carter et al. 1992). In toto, such development often eventually comprises an incipient foredune zone. Such foredunes may be seasonal if formed in annual plants, and require invasion by perennial plants in order to survive. Plant species type is important in determining morphological development; species such as the tall, dense *Ammophila* tend to produce higher, more hummocky peaked dune forms than lower, more spreading, rhizomatous plants such as *Spinifex* or *Ipomoea* which produce lower, less hummocky dune forms (Hesp 2002).

Incipient foredunes may also form on the backshore by relatively laterally continuous alongshore growth of pioneer plant seedlings in the wrack line or spring high tide region, and/or by rhyzome growth onto the backshore region (types 2a and 2b of Hesp 1989). Morphological development principally depends on plant density, distribution, height and cover, wind velocity and rates of sand transport. Plant growth, density and distribution can also vary seasonally, and therefore seasonal growth rates (low [or even absent in high latitudes] in winter, high in spring) strongly influence patterns of sand transport and deposition on incipient (and established) foredunes (Davidson-Arnott and Law 1990; Law and Davidson-Arnott 1990). Secondary factors such as the rate of occurrence of swash inundation, storm wave erosion, overwash incidence, and wind direction can also be important in determining subsequent dune evolution (Hesp 2002).

3.5.1 Flow Dynamics in Vegetation

The flow dynamics within and over individual plants and continuous plant canopies varies considerably. Relatively continuous plant canopies variously impact the wind/sand flow depending on plant density, shape or morphology, distribution and height (e.g. Buckley 1987; Aylor et al. 1993; Raupach 1992; van Dijk et al. 1999). Van Dijk et al. (1999) demonstrate in their modelling that as plant height increases, dune height increases and dune length decreases. Such work verifies field observations (Hesp 1989; Arens et al. 2001). High, dense canopies (e.g., grasses such as *Ammophila* sp., shrubs and trees such as *Atriplex* sp. in Western Australia and poplars on the Great Lakes in Canada) act to reduce flow velocities very rapidly (Hesp 1989; Niedoroda et al. 1991;

Jacobs et al. 1995). Sand transport (saltation and traction) is markedly reduced from the leading edge. Incipient foredunes tend to be asymmetric with the short slope to seawards. Lower plant canopies (e.g. *Spinifex* sp., *Uniola* sp., *Ipomoea* sp.), act to reduce the flow and transport more slowly so that there is often a gradual downwind reduction in transport and asymmetric dunes are formed with the short slope on the downwind (lee slope) side (Hesp 2002).

3.5.2 Tropical Versus Temperate Foredune Trends and Morphologies

While it may be seen from the brief discussion above that a significant number of factors influence incipient (and subsequently) established foredune morphology, plant morphology and density and dominant mode of growth are critical factors, since these strongly influence sediment transport and deposition within plant canopies.

While temperate coastal zones can have a number of pioneer plant species, there is commonly one or two dominant species responsible for forming foredunes. Such species include grasses and sedges such as *Ammophila arenaria, A. littoralis, Carex* sp. *Festuca* sp. *Elymus farctus, Spinifex* sp., *Panicum* sp., *Spartina* sp., *Sporobolus* sp. and other species such as *Eryngium*. In contrast, low, creepers or trailing plants are more common in the tropics (but with varying numbers of grass, sedge and herb species).

There is commonly a gradient in coastal dune vegetation species with latitude, such that an individual or group of species, particularly pioneer species, dominate one latitudinal region and slowly give way to another species or group with an increase or decrease in latitude (Johnson 1982; Cordazzo and Seeliger 1988; Hesp 1991; Moreno-Casasola 1988, 1990, 1993; de Lacerda et al. 1993; Pfadenhauer 1993). As one trends from temperate climates towards the tropics in both eastern and western Australia, Brazil and South Africa (e.g., Doing 1981; Tinley 1985; Frazier 1993; Weisser and Cooper 1993; Müller 1980; pers. observ.; de Lacerda et al. 1993) there is a trend from a predominance of grasses, herbs and subshrubs to creepers, and a particular predominance of creepers in the tropics (e.g. Whitmore 1975; Moreno-Casasola 1988). The creepers are dominated by *Ipomoea* and *Canavalia*, both of which are low, prostrate, rhizomatous species which can very rapidly grow across the backshore under accretionary conditions. This is the so-called '*Pes-caprae* formation' of Schimper (1903) or '*Ipomoea pes-caprae – Canavalia* associes' (Richards 1964). Their rapid seawards growth potential, plus low creeping or trailing habit tends to lead to the development of low, terrace type incipient and, in some cases established foredunes (Davies 1980, his Fig. 115; Lee 1993, his Fig. 6.4). Of course, a slow rate of sediment supply and low winds probably aid this morphological development and may account for the limited foredune development seen in parts of the humid tropics. Thus, all other factors

Fig. 3.4. a *Spinifex sericeus* incipient foredune ridge, Mahia Penninsula, New Zealand. **b** *Ipomoea* incipient foredune terrace at Tioman Island, Malaysia

being equal (and there are rather a lot of factors!), one should see a general tendency, at least with incipient foredunes, for foredune *ridges* to be formed in the distal parts of the tropics (away from the equator) and within temperate zones where pioneer grasses tend to dominate (e.g. Hesp 1991; Polunin and Walters 1985). Foredune *terraces* should be more common nearer the equator (Fig. 3.4a, b).

3.6 Gross Dune-Field Morphology

If one considers the gross, large-scale morphology of entire transgressive and parabolic dune fields (i.e. ignore the dune types present on them), one can distinguish at least two major forms, namely tabular and buttress types (Tinley 1985; Hesp et al. 1989; Hesp and Thom 1990). Tabular dune fields tend to be broad plateau-type sand bodies (Hesp and Thom 1990; see Figs. 23.3 and 23.4 of Wiedemann 1993), while buttress dune fields are triangular, landward ascending ramps (similar to the buttresses of rain forest trees; Tinley 1985).

In very general terms, buttress dune fields are more common in the tropics and adjacent humid subtropics than in temperate areas (with some exceptions below). Buttress dune fields occur where dune fields are migrating obliquely onshore or perpendicularly onshore and where sand is migrating or advancing into tall forest margins. Tropical forest may be a more capable barrier to dune migration than temperate forest due to greater growth rates (see below), higher species richness and the height tropical forest trees may grow to. Thus, dune fields would build up against such forest becoming more buttress-like compared to migration over temperate and Mediterranean grasslands, heathlands or forest. For example, if one compares the development of parabolic and transgressive dune fields on the Australian west coast above the Tropic of Capricorn with the east coast above the Tropic, there are no buttress-type dune fields on the west coast where dunes are typically migrating into grassland or low heath (Hesp and Chape 1984; Hesp and Curry 1985; Hesp and Morrissey 1984). Pioneer tropical species may be more capable of colonising and stabilising dune slip faces and precipitation ridges, thereby increasing the chances of creating high, marginal, landward ascending precipitation ridges.

Examples of such buttress dune fields are common along the east coast of South Africa extending from below the tropic and up into Mozambique and Kenya (Tinley 1985; Weisser and Cooper 1993; Weisser and Marques 1979; Frazier 1993). Some of the parabolic and transgressive dune fields of central and NE Queensland are commonly buttress-type dune fields, although there is also a strong Pleistocene dune inheritance in many cases. The large sand islands extending north from around Stradbroke Island (28°S) and many of

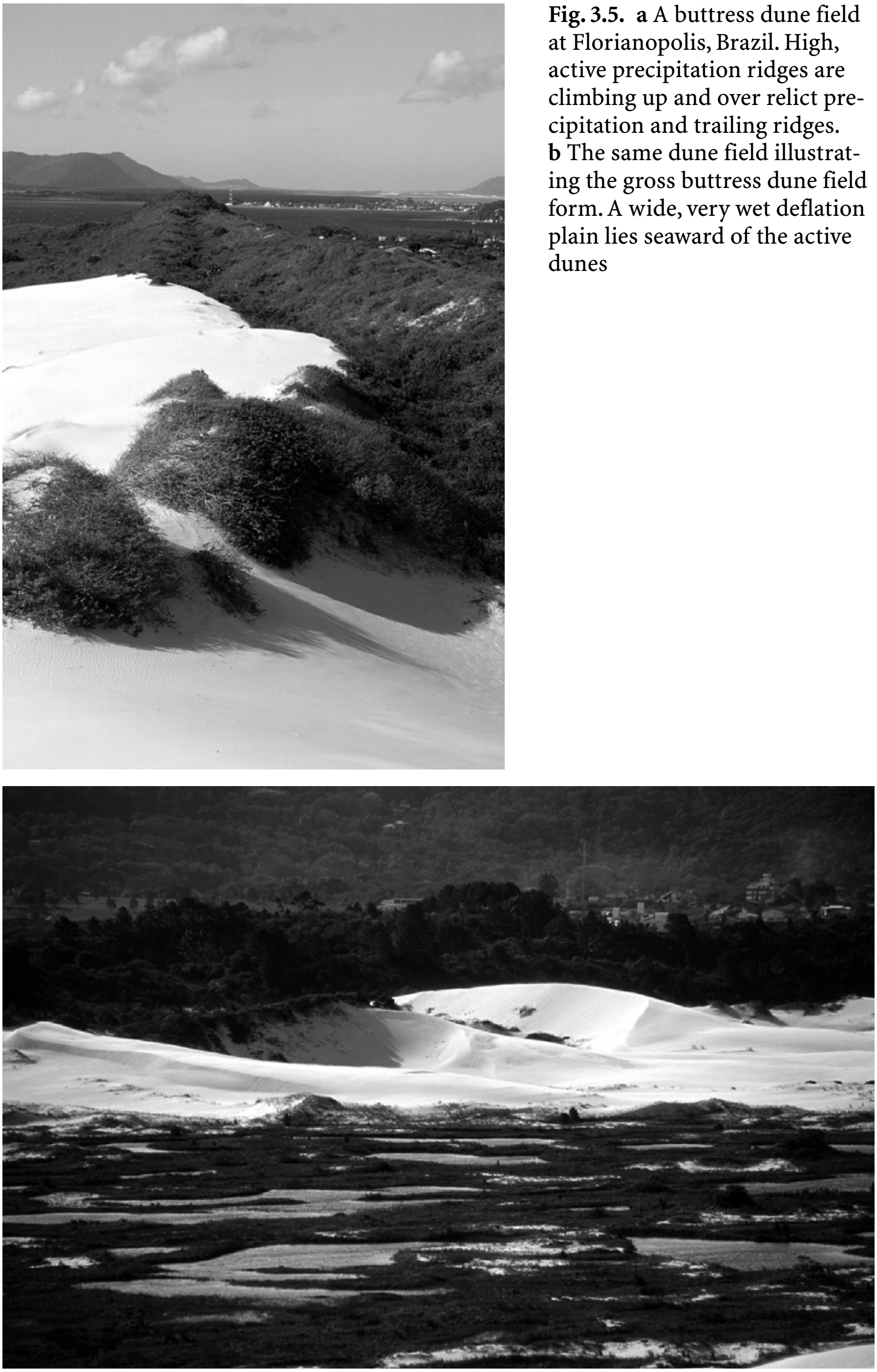

Fig. 3.5. a A buttress dune field at Florianopolis, Brazil. High, active precipitation ridges are climbing up and over relict precipitation and trailing ridges. **b** The same dune field illustrating the gross buttress dune field form. A wide, very wet deflation plain lies seaward of the active dunes

the dune fields north to Cape York (around 10°45′S) can be included in this group (Thompson 1983; Pye 1983a, b; Batianoff and McDonald 1980).

In the Torres area of Brazil (around 29°S), tropical forest species are locally present due to the closeness of the mountain range and locally higher rainfall. In this area, buttress-type transgressive dune fields occur with high marginal precipitation ridges (Fig. 3.5a, b). To the south and north of the Torres region, the tropical elements disappear, and the dune fields are wide, low and tabular with remarkably low, small precipitation ridges.

Exceptions occur due to factors such as Pleistocene inheritance and accommodation space. In some cases, Holocene dunes are a relatively thin veneer of sand overlying extensive, multiple Pleistocene dune phases and these may provide the base, underlying ramp morphology (Pleistocene inheritance) upon which the Holocene dunes have climbed landwards to form buttress dune fields. In other cases, a buttress-type gross morphology may be the only form possible if the accommodation space for dune building is small or steep bedrock occurs adjacent to the beach.

Note that there are many sections of coastline within the tropics that are characterised by foredune plains rather than parabolic and transgressive dune fields (e.g. Dominguez et al. 1987; Dillenburg et al. 2000). The writer is presently not aware of any major gross morphological differences between foredune plains in the tropics and temperate regions. Swales in the humid tropics may be much wetter, have more permanent and seasonal wetlands and contain mangrove swamps in some areas (e.g., the massive foredune plains of Eighty Mile Beach, NW Western Australia (Hesp, pers. observ.).

3.7 Rate of Dune-Field Vegetation Colonisation and Re-Vegetation Processes

Vegetation processes, particularly growth rates, are, on average, greater in the tropics than in temperate regions (Schimper 1903; Walter 1973; Collinson 1977; Kellman and Tackaberry 1997). Very rapidly growing plants are quite common in the tropics, especially in those tropical areas that experience more rainfall, and less seasonal drought or dry period.

Thus, one would anticipate that vegetative colonisation of, and re-vegetation processes in dune fields should occur at a faster rate in the tropics that in temperate regions. This should mean that there would be a greater chance of preservation of original dune form following vegetative colonisation and stabilisation in the tropics than in temperate regions. Figure 3.6 illustrates a transverse dune slipface being colonised and stabilised by *Croton punctatus* and *Chamaechrista chamaecristoides* species in El Quixote, Mexico. Comparison of aerial photographs over several years indicates that this process occurs very rapidly, and that preservation of original to near-original dune form can

Fig. 3.6. A transverse dune slip face in the El Quixote transgressive dune field in Mexico being rapidly stabilised by *Croton punctatus* and *Chamaechrista chamaecristoides* species

be quite high. Such near-perfect preservation of original dune form does not appear to be as common in temperate regions (Thom et al. 1992).

3.8 Types of Dune-Field Vegetation Colonisation and Dune Morphologies

In the Veracruz region of Mexico (centred around 19–21°N) on the east coast (mean annual temperature 23 °C, rainfall 1600 mm; Moreno-Casasola 1993), there are a number of both active and vegetated transgressive dune fields. The vegetated dune fields are far more extensive than the active ones and are characterised by multiple, long, narrow, relatively straight, sometimes sinuous ridges. These ridges are formed in two principal ways; either by the vegetative colonisation of the margins of transverse and aklé dune ridges, or by precipitation dune ridge formation on the edge of the active dune field (Fig. 3.7).

As a transverse dune migrates downwind, and in most cases in this region, alongshore, it may be colonised along the seaward and landward margins by vegetation. This colonisation may take place in at least two ways as follows:

1. Pioneer (backshore/foredune) vegetation such as *Ipomoea*, typically growing initially on the backshore, colonises the base of the dune side slope,

Fig. 3.7. Vertical aerial photograph of the Dona Juana transgressive dune field in Mexico. Note the multiple, subparallel trailing ridges present in the vegetated portion of the dune field

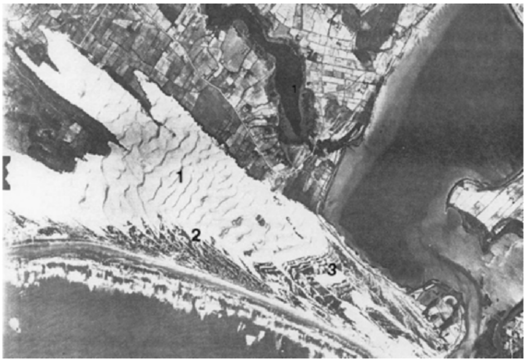

Fig. 3.8. Vertical aerial photograph of the Ibiraquera transgressive dune field, Brazil showing transverse dunes (*1*), trailing ridges formed from the margins of transverse dunes (*2*), and gegenwalle ridges formed within the deflation basins (*3*). Ground distance across the photograph (*left* to *right*) is 4 km

grows up the slope and partially stabilises the dune ridge margin and crest. Other pioneer and intermediate species propagate within the *Ipomoea* and assist in the stabilisation process.

2. Pioneer (transgressive dune field) vegetation such as *Croton punctatus* and *Chamaecrista chamaecristoides* in Mexico (Martínez and Moreno-Casasola 1998) colonise the outside slope margin (and eventually the crest) of the transverse dunes. The plants may relatively uniformly colonise the whole slope and eventually the crest, or may form individual hummocks (or nebkha) along the dune slope crest trapping the sediment and forming a ridge as the dune migrates away. Ridge formation takes place in similarity to parabolic dune trailing ridge formation – the outside slope and crest of the ridge is relatively stable and vegetated while the main part of the dune migrates away. Because the ridge is initially formed at the highest point on the dune (the slip face crest side), as the dune moves away, the upwind dune slope edge is held by the vegetation and the "inside" part is eroded forming a ridge. As it does, it leaves the vegetated crest edge behind and forms trailing ridges (Fig. 3.8). Two trailing ridges can be formed at the same time on each side of a transverse dune. If there are several transverse dunes in the dune field, as is common, multiple trailing ridges can be formed at one time.

Fig. 3.9. **a** Ibiraquera dune field, Brazil. *Spartina ciliata* and *Andropogon* species colonising the margins of transverse dunes as the dunes migrate downwind. **b** Ibiraquera dune field, Brazil. Looking north and upwind 180° around from the position of **a** showing where the transverse dune once was, the inside erosion of the stabilised edge of the dune and the formation of the trailing ridge

Similar trailing ridges form behind barchans, mega-barchans, and barchaoidal transverse dunes in NE Brazil near the equator (Maia et al. 1999; Jimenez et al. 1999), and are common in transgressive dune fields in Brazil down to 27–28°S (Figs. 3.3, 3.9a, b).

In the Mexican dune fields mentioned above, and in Baja California Mexico dune fields (mostly lying up to a few degrees north of the Tropics), various species (*Croton punctatus* and *Chamaecrista chamaecristoides* in the Veracruz region) commonly form en echelon chains of nebkha hummocks forming quite long, straight, hummocky ridges also. These occur following the establishment of one shadow dune behind a plant. Seeds are presumably trapped in the low velocity, leeward protected shadow zone and establish a new plant. The process continues, leading to the development of en echelon shadow dunes and nebkha aligned downwind in the direction of the dominant wind. These are formed almost anywhere in the dune fields from deflation plains to upper dune crests and higher dune margins (Fig. 3.10).

Observations in other temperate transgressive dune fields (e.g. Cooper 1958, 1967; Goldsmith 1978; Hesp and Thom 1990; Hunter et al. 1983; McLachlan et al. 1987; Hesp et al. 1989; Borowka 1990; Orme 1990) indicate that such within-dune field trailing ridge development and re-vegetation processes is uncommon to absent (although quite common in parabolic dune fields). The

Fig. 3.10. En echelon nebkha and shadow dunes forming ridge lines at Guerrero Negro, Baja California, Mexico. This area is outside the tropics at 28°N, but illustrates one typical pattern in semi-arid to arid coastal dune fields seen both within and adjacent to the tropics

answer again may lie in factors such as species presence, the adaptive strategies of tropical – subtropical dune-field specialists, greater rates of plant growth, or other factors. Clearly more research is required.

3.9 Conclusions

Tentative conclusions are as follows:

1. Taller grasses, sedges and a variety of pioneer species dominate the incipient foredune zone in temperate regions while low, creepers dominate in the tropics. One should see a general tendency, at least with incipient foredunes, for foredune *ridges* to be formed in the distal parts of the tropics (away from the equator) and within temperate zones where pioneer grasses tend to dominate, and foredune *terraces* should be more common nearer the equator.
2. In very general terms, buttress dune fields are more common in the tropics and adjacent humid subtropics where the dune fields are migrating obliquely onshore to onshore (not alongshore) than in temperate areas where tabular dune fields are more common (with some exceptions). On average, precipitation ridges should be higher in the tropics compared to temperate regions.
3. The vegetative colonisation of, and re-vegetation processes in dune fields should occur at a faster rate in the tropics than in temperate regions. This should mean that there would be a greater chance of preservation of original dune form following vegetative colonisation and stabilisation in the tropics than in temperate regions.
4. The modes of vegetation colonisation within tropical dune fields appear to be greater than in temperate dune fields. The result is that within-dune-field trailing ridge development is common, and a variety of re-vegetation processes and locations occur in the tropical dune fields compared to temperate dune fields.

Acknowledgements. My thanks to Marisa Martinez for her superb hospitality, for making me write this paper and for showing me the Mexican dune fields; to Caroline (Thais) Martinho for her assistance in the literature search; Tim O'Dea for his unstinting support; Sergio Dillenburg, Lauro Calliari, Luiz Tomazelli, Thais, Paulo Giannini, Luciana Esteves, Nelson Gruber, and Parente Maia for their fantastic hospitality, support and visits to Brazilian dune fields.

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