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Sand colour at Cuba and its influence on beach nourishment and management

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ABSTRACT

The colour of 93 beaches in Cuba was assessed in CIEL*a*b* colour space. Study sites comprised exposed and sheltered mainland beaches and keys. Notwithstanding the limited extension of this country, beaches show real colour variability due to mineralogical differences in rock outcrops in the various watersheds, the proximity of the coral reef and the shell fragments originated in open coast or mangrove areas. PCA performed on the L*, a* and b* parameters allowed beach groupings which fitted with their geographical locations and identified those altered by beach nourishment. Sand lightness was considered by taking into account visitor's preferences, addressed to very clear sand, which is infrequent in mainland Cuba. One strongly coloured beach was found, for which a geosite institution is proposed. The impact of beach nourishment on native sand colour was studied and the beach at Varadero, probably the most popular Cuban beach, was negatively impacted by this activity. Reconstruction was necessary after severe erosion induced by Sea Level Rise and hurricanes. Recommendations for wise beach nourishment in tropical areas are given.

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1. Introduction

Beach colour is a primary component of the coastal landscape (Pranzini et al., 2010; Tsujimoto and Tamai, 2013) and is determined both by mineral type and/or rock fragments present (e.g. Wiegel, 2006; Kasper-Zubillaga et al., 2007) and/or by organic fragment occurrence (e.g. Calhoun and Field, 2008; Short and Woodroffe, 2009) which are frequently mixed in different proportions (e.g. Carey et al., 2009; Gómez-Pujol et al., 2013). Tourists' preferences are for white and golden sand (Williams and Morgan, 1995; Williams and Micallef, 2009), with a progressive dislike of the beach as sand becomes darker in colour (Pranzini and Vitale, 2010).

Sand colour is especially important on tropical beaches, where foreign tourists ask and desire white sand much more than in mid latitude beaches (Baldacchino, 2010). Influenced by travel agency brochures and TV documentaries, who strictly associate a tropical beach with white coral sand, tourists are frequently disappointed to find dark coloured – if not completely black, *e.g.* derived from basalt rocks – sand, which is frequently found on many volcanic islands.

Nevertheless, light-colour beaches are not as frequent along tropical littorals, as Coastal Scenic Assessment studies performed in different countries has demonstrated (Anfuso et al., 2014; Botero et al., 2013; Rangel-Buitrago et al., 2013).

Although "bathing" tourism is the main tourism market component in tropical countries, one must not forget the growing interest in geosites, which frequently gives an added value to the traditional "Sun, Sea, Sand" offer (3s market). The specialist beaches

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given below certainly attract tourists in abundance. Beaches, comprising specific minerals, usually heavy minerals that accumulate rather than being winnowed away, can be considered geosites potentially attractive for visitors. Examples are: the black chromite rich beach at Marasimsim, or Punalu'u Beach, Hawaii, derived from weathering/erosion of basalt rocks that form the island; red and pink, *e.g.* Lombok beach, Indonesia, pink as a result of the presence of a foraminifera (Wiratama et al., 2014); and the pink garnet pocket beach at Tanjung Simpang Mengayau, both in Malaysia (Muda, 2013); green, as in Papakōlea Beach, Hawaii, the colour coming from olivine eroded from basalt rock. White gravel beaches can attract tourists as well as geosites, such as the artificial marble beaches in Tuscany, comprising by-products of the Apuan Alps marble quarries from which Michelangelo took his block to sculpture David (Nordstrom et al., 2008).

The bulk of the world's tourism – one of the largest growth industries in the world and expected to reach 1.6 billion international tourists by 2020 (http://tourismconcern.org.uk/), – tends towards beaches which can be described as 'golden sand/white' ones. These beaches are a tourist industry strategic resource for countries basing a relevant part of their economy on this sector, e.g. Cuba (Taylor and McGlynn, 2009), which derives approximately half of its hard currency from this source, with 2.8 millions international arrivals in 2014, a 5% increase compared to 2013 (UNWTO, 2015). In addition, Cuba, with normalization of US relations in progress, will surely see a further increase in international tourists. Institutions responsible for tourism should therefore identify, promote and protect these beaches.

Cuban beaches, like many others in tropical environments (Wong, 2003), are severely eroding as a result of Sea Level Rise (UNEP/GPA, 2003), high energy low frequency events, namely Hurricanes (Tristà Barrera et al., 2008; Montero and Martì, 1996) and sand beach quarrying (Rodríguez Paneque et al., 2009). Therefore artificial nourishment is necessary to protect coastal settlements and maintain a dry beach large enough to support the tourist industry. Davison et al. (1992) produced a bibliography of nourishment, emphasising design (cross and alongshore), grain size, placement and project evaluation, but no mention of colour is present, and little has changed since then. The main concern of any beach nourishment project is still fill stability (Gravens et al., 2002). However, by disregarding the colour of the sand, a result can be environmental economic damage (Pranzini and Vitale, 2010).

The present paper provides a first archive of the colour of 93 beaches in Cuba, analysing how beaches of different colours are used by local and international tourism, and shows how beach nourishment at Varadero, one of the most important tourist district in Cuba, has negatively changed its attraction.

2. Methods

Berm sediment samples were collected mid way between the up-rush line and dune foot at 93 beaches in Cuba (Figs. 1 and 2) while performing Coastal Scenery Assessment in June 2012 and May 2015 (Anfuso et al., 2014; Anfuso et al., in prep.) from those exploited mainly by the international tourism sector, such as, Varadero, Cayo Santa Maria, Cayo Coco and Cayo Largo, to those frequented exclusively by locals (e.g. Playa Piloto, in Camaguey). They ranged from urban beaches (e.g. El Tenis and El Judio, in Matanzas) to the most remote ones, e.g. Cajuajo, in Guantanamo. Geographical distribution is uneven, since most of the south-west coast is bordered by mangroves (Menéndez et al., 2004). One sand sample collected at Varadero in the early 80s, *i.e.* before beach nourishment, and preserved in a sealed glass bottle was also considered.

Colour determination using CIEL*a*b* 1976 colour space (Pranzini et al., 2010) was performed within 10 days after sampling following removal of "visible" vegetation debris (Table 1). CIEL*a*b* is one of the most uniform colour space certified by the Commission Internationale de l'Eclairage (CIE, 1976) and is therefore

Fig. 1. Location map of the studied beaches. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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