14 Recent Landscape Change in Somalia Monitored Through the Use of Repeat Photography

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Abstract

Using archival vertical and oblique aerial photography (1945–68) and thematic maps, we present observations on landscape change in Somalia, on the Juba and Shabelle River Inter-Riverine, along the coastal sand belt, and among the vegetation arcs and landscapes of the north. Our work does not cover all of Somalia but presents case studies, based on our work in agricultural development, food security and conservation projects that, in the Inter-Riverine area, the authors worked on in the 1980s. We also examine changes in Somaliland and Puntland, repeating Trimetrogon photography of vegetation arcs and desert scenes and photography from a USAID project. The online grey literature archives of WOSSAC at Cranfield University and FAO-SWALIM have provided legacy materials, and Google Earth has been central in making repeats, where one cannot go on the ground today. Google Earth can be adopted as a useful and free tool to make meaningful repeat shots of older oblique aerial photography as a monitoring tool in change detection. Conclusions are drawn on each study, and proposals are made for future investigations to follow up on the assessments and make a more systematic use of the archival aerial photography.

Keywords

Repeat photography • Trimetrogon aerial photography • Juba Shabelle Inter-Riverine • Forest and land use change • Sand dune stabilisation

14.1 Introduction

This chapter has adopted repeat photography methods (Webb et al. 2010) to examine change in land cover, land use and the physical landscape in parts of Somalia (taken here to include the countries now designated as Somalia, Somaliland and Puntland). Repeat photography/repeat imagery methods aim to return to the same position and assess change on the ground from that location. We have made this assessment at numerous locations in Somalia by utilising archive materials. A poster, presented at the 2011 AIG Conference in Addis Ababa, highlighted one of the main archives, a collection of Somalia aerial photography (AP) mosaics made by Hunting Surveys Ltd (HSL) and its possible uses (Paron and Munro 2011). In this chapter, we provide examples of uses.

Munro (RNM) first used repeat photography of landscapes in Jordan (for 1953–1990 period). In Darfur, Sudan, land cover changes have been compared for the 1994–2020 period (work in preparation). Later he used georeferenced older AP and mosaics to assess sand movement in Sudan (Munro et al. 2018; Munro and El Tom 2009) and Arabia (HTS 1999; Munro and Wilkinson 2007; Munro et al. 2012, 2013). In Tigray, Ethiopia, he has assessed changes to land cover over 45 years (Nyssen et al. 2007, 2008, Nyssen et al. 2009a, b, 2010a, b, 2014; Munro et al. 2008 and 2019; De Mûelenaere et al. 2014).

The present work makes a preliminary review of selected images from development studies and air surveys made in Somalia between 1945 and 1985 to determine what was

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assessed, what was planned in the studies we worked on and how has land use changed over the intervening period to 2020 as far as this can be followed from the published and grey literature and also an important source to gauge change, the remarkable twenty-first-century armchair geographer's tool, Google Earth ©. We have been able to substitute Google Earth for the aerial camera to repeat oblique and vertical images. The Google Earth repeats are not perfect of course—higher-quality imagery acquired from a research budget and taken at the same repeat times would be necessary—but we regard them as a good introduction.

This chapter does not cover all of Somalia but presents case studies, most drawn from data of development projects and studies the authors worked on in the 1980s, and include reports, maps and our own terrestrial and aerial photography. The examples in this paper are drawn from archived aerial photography (AP) and mosaics and selected from 210 terrestrial and oblique aerial photographs made by the authors (Fig. 14.1).

14.2 Data and Methods

14.2.1 Sources of Archival Aerial Photography and Mosaics

Archival aerial photography (AP) remains the best material to examine past landscapes over a long interval; the high resolution of AP can identify even a tussock grass, and under the stereoscope and using other photogrammetric tools, the structure of vegetation can be quantified. In 1972, on soil surveys in the Awash Valley of Ethiopia RNM used colour AP that showed shrubs <50 cm diameter, and while ERTS (Landsat) MSS false colour imagery acquired from NASA was tremendously exciting to use in the field, it had low resolution (Parry 1974); satellite imagery of any use in soil surveys only became very roughly comparable to AP with the introduction of SPOT imagery in the 1986, but SPOT still had only a 10 m resolution. Today high-resolution imagery is almost taken for granted, but AP remains the only

Fig. 14.1 Location map

available material for detailed examination of landscapes before the 1980s. Fortunately, AP archives exist for Somalia.

We believe, though unverified, that the earliest aerial photography of the Inter-Riverine area—the lands within the Juba and Shabelle basins in Somalia—was flown by the Italian Air Force for Istituto Geografico Militare (IGM) during the 1930s, and is in an, so far undocumented, IGM archive in Florence, not included on the IGM's (now IGMI) online digital repository. The British Royal Air Force (RAF) flew parts of Somalia in the 1940s for wartime use, but most of the East African campaign materials are thought to have been destroyed at the end of WW II. During 1944–45, the United States Army Air Force (USAAF) flew 1:40,000 scale Trimetrogon (TMG) AP over Somalia using photo-reconnaissance B-24 aircraft, fitted with three K-17 cameras (one vertical and two oblique). These flew at a height of 20,000 ft (6096 m) on east–west aligned paths, approximately 40 km apart (Livingstone 1964). Hunt (1952) noted that a nearly complete set of 1945 Trimetrogon photographs was handed over to Director of Agriculture and Veterinary Services (DAVS), Hargeisa, in 1951. It is unlikely to be there, but Trimetrogon photography is available through the National Archives of the USA (information from the National Collection of Aerial Photography (NCAP), Edinburgh, UK, in 2019). From 1946 to 55, the RAF flew blocks of Somaliland that were used in the compilation of the Directorate of Colonial Surveys DCS39 series of topographical sheets at an approximate scale of 1:125,000.

For this study, we have used a few Trimetrogon images from 1945, terrestrial and aerial photography taken between 1958 and 1984, and compared these to recent satellite imagery. Our principal source has been the uncontrolled air photo mosaics constructed by Hunting Surveys Ltd. (HSL) in the 1960s and early 1970s from 1958 Royal Air Force AP. Very considerable efforts and skills went into making the semi-controlled mosaics by HSL staff: the central parts of aerial photos were used, photos were laid down over existing topographical maps, and coordinates of observable points on topographical maps were identified on AP to give as accurate a location as possible. Though they were not constructed as orthophoto maps, the workmanship makes them satisfactorily accurate for modern change detection studies.

The HSL Somalia mosaics used 1958 Royal Air Force AP, and these mosaics were constructed periodically at intervals for prospecting oil companies from 1960 to mid-1970s. The RAF cover provides a quality timeline view of the country at 1958: a period before satellite imagery became available and before imagery could start to match the resolution of AP. In the early 1970s, Landsat (originally called the Earth Resources Technology Satellite—ERTS) imagery became available that could be rectified, but resolution was small: comparing Google imagery and a 1:500,000 scale colour composite ERTS image of the upper Shabelle Valley in Somalia acquired on 26 January 1973 and made by HSL, it is difficult to see the vegetation arcs that cover this region (see Sect. 14.9). Later, as satellite imagery was of higher resolution, and became digitally multispectral, it was cheaper per km^2 to acquire than AP. But importantly, the accuracy of the old mosaics could be checked. As resolution increased, AP on a grand scale was phased out, but remains as a superlative tool to compare with modern digital and multispectral formats. It is also essential for stereo interpretation. These AP mosaics cover almost all of Somalia as shown in Figs. 14.2 and 14.3.

Table 14.1 is a provisional list of Somalia AP and mosaics and provides details, as best as can be produced, of the former HSL AP negative mosaic archive and other collections. The HSL Somalia mosaic archive (>450 large negatives) was saved from destruction by RNM in 1986 and, after many years of private storage, now in the care of NCAP, to whom inquiries for further use should be addressed (http://ncap.org.uk/). This table is incomplete as other materials remain unseen: the IGM archive believed to be extant in Florence and Royal Air Force cover from WW2. The RAF flew much of Somalia from 1947 to 1958, and their photography was used several times by HSL to make mosaics. HSL had copies of the RAF films to make prints. Other AP used in mosaics was flown 1959–60 for the Standard Vacuum Oil Co and Mineraria Somalia. These surveying companies used a wide range of AP cameras including RC 5a, RC 8, RC 9 and Eagle IX. HSL also flew some 1:30,000 colour AP, in January and February 1970 of the Bur Region for Sinclair [HSL-SOM-COL-70:2–10], but prints and films were destroyed around 1985. In 1983–84, new photography was flown by Air Survey and Development (ASD) Gmbh (Frankfurt) at 1:30,000 scale, and 1:100,000 scale mosaics, for the National Tsetse and Trypanosomiasis Control Project (MMP 1983) in the Inter-Riverine area, were delivered to Mogadishu in 1985. However, inquiries at this time have not determined where this 1983–84 AP archive might be. From the 1960s up to 1985, a large AP archive existed at the Survey and Mapping Services of Somalia in Mogadishu. Its current status is not known, but it is likely it did not survive the civil war; the status of similar archive of old AP in Hargeisa is unknown.

14.2.2 Baseline Sources on Natural Resources Assessment

From 1962 to 65, Lockwood Survey Corporation made for FAO the *Agriculture and Water Survey of the Somalia Republic* (FAO/SF:42 SOM; Lockwood/FAO, 1969). The FAO soil studies used the HSL 1:60,000 scale mosaics, and the study produced useful data with a colour soil map at 1:500,000 scale (Fig. 14.4). Slightly later, Hunting

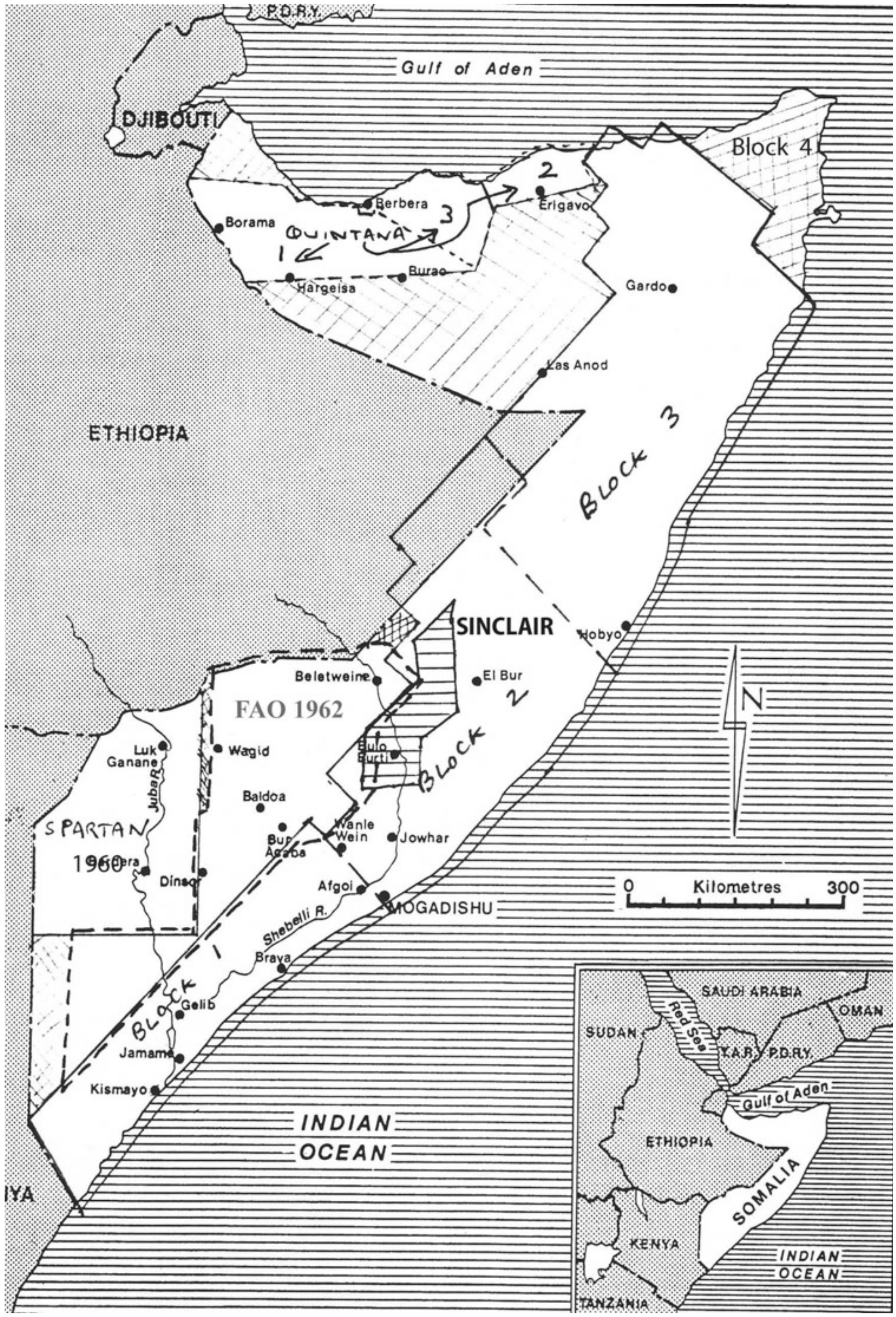

Fig. 14.2 Aerial photo mosaic cover of Somalia (Hunting). Refer to Table 14.1. Details made by Munro at Hunting Survey Records 1986 Original drawings donated to NCAP, Edinburgh 2020

Technical Services (HTS) and Sir Murdoch MacDonald and Partners (MMP) conducted the *Project for the Water Control and Management of the Shabelle River* (HTS-MMP 1969). These were both key baseline efforts that remain very useful. Comparative studies on the Juba River had been made by Selchozpromexport in 1965 and were updated by Technital (1975). On the irrigation and rainfed projects planning studies described in this chapter, we utilised the maps and the soil data from a series of feasibility studies made from 1977 onwards by HTS and MMP in the Inter-Riverine area (HTS 1977a, 1977b, 1978a. 1978b, 1979, 1982, 1984; MMP, 1978a, 1978b, 1980, 1981, 1983, 1985). In the north, Somaliland and Puntland, RNM refers to a 1960s USAID-funded agricultural development project (Wixom 1963, 64; Erdmann 1993; McCarthy et al. 1985); to Trimetrogon oblique AP from 1945 and 1958 Royal Air

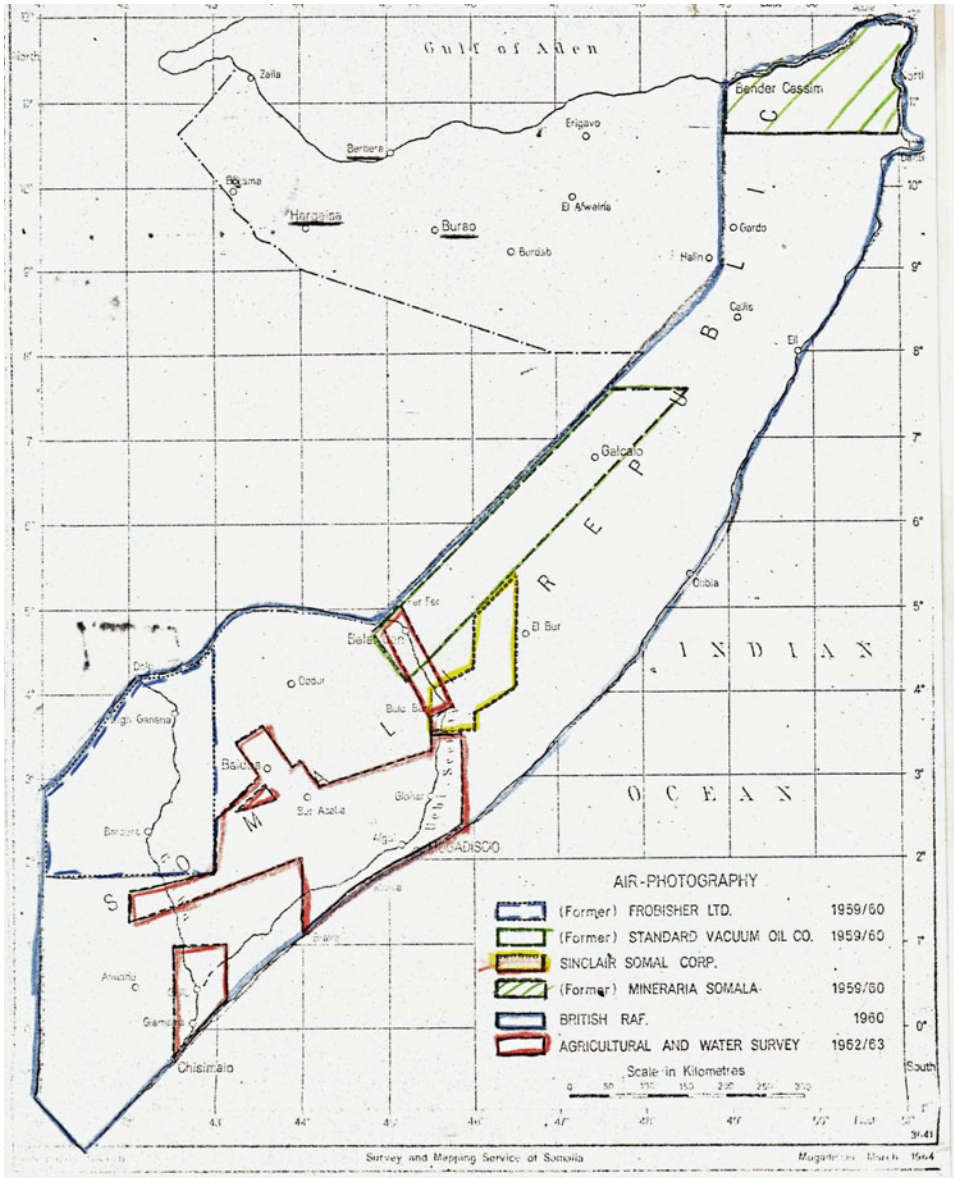

Fig. 14.3 Aerial photo mosaic cover of Somalia. Refer to Table 14.1. A 1964 sketch map from the *Survey and Mapping Services, Mogadishu*. It was salvaged from Survey Records at Hunting Surveys Ltd in 1986. Original drawings donated to NCAP, Edinburgh 2020

Force AP made into mosaics by HSL. For the 1975–76 Somalia Livestock Sector Review, a hydrogeology map at a scale of 1:2 million was made of the entire country (HTS/Gunn Rural Management 1978) and most usefully shows all known springs, wells and boreholes at that time.

Our assessment has been aided by documents held in WOSSAC archive in the UK (www.wossac.com) and the SWALIM archive in Nairobi (www.faoswalim.org). Other useful sources can be found in the Earth Resources bibliographies compiled by Kalb (2000) and Hadden (2007) and the coastal and marine bibliographies of Morcos and Varley (1990) and PERGSA/GEF (2002).

The spelling of place names in Somalia often uses English, Italian, older and modern Somali names and Russian derivations on their maps at 1:100,000 and 1:200,000. Apart from spelling of Mogadishu, we use the convention that names are as placed in the reports at the time of our studies: Hadden (2007) agreed and provided pertinent guidance for the wide range of place name spellings in Somalia.

14.3 Agricultural Development in the Inter-Riverine and Mudug

14.3.1 Cycles of Drought and Flood

Drought and flood conditions have long been regular features of life in southern Somalia. In 1941–42, as Allied forces pushed into Somalia from Kenya and dislodged the

Table 14.1 Older aerial photography and mosaic cover of Somalia

AP Cover/block name	Area	AP Operator. Year flown and scale and notes	Mosaic scale	Mosaics	Hunting mosaic series no.	Notes
Instituto Geografico Militare	Not known	1930s flown by IGM. Materials reported to be at IGM archive, Florence	Not known	No data	Not applicable	Not yet seen
Trimetrogon	Whole country	United States Air Force, 1945, 1:40,000 (vertical right and left oblique AP), held by National Archives	Not known if any made	No data	Not applicable	Available at US National Archives
Somalia	Parts of country	RAF, 1946–1953—sorties 13/SOM; 13B; 683A; and HAS 1958, sorties HAS/B/SOM/58. (holdings at Rhodes Library, Bodleian, Oxford)	Not known but believed some used by HSL for mosaic series	No data	Not applicable	Photography at Bodleian archive
Somalia	Whole country	Royal Air Force, V58. 1:60,000 (vertical AP)	Used by HSL to make as listed below	See below	Used in mosaics listed below	Prints at NCAP
Area A Somalia	El Wak Project. Area A Somalia. Juba River	Spartan Air Services. 1959–60. 1:30,000	1:82,600	47	HSL used Spartan mosaics 1–47	Spartan Air Services, Canada for Frobisher Oil Co Ltd. Later used by HTS. Negatives at NCAP
Sinclair Blocks 1, 2,3	Block 1: South-west Block 2: Central Block 3: N central	RAF 1958 (also some from 1947 onwards) all at 1:60,000	1:60,000 (also, at scales of 1:100,000 and 1:200,000)	Block 1: 150 Block 2: 33 Block 3: 49	Block 1: D-5824 Block 2: D-5868 Block 3: D-5874	HSL for Sinclair
Sinclair Block 4	4: NE Somalia	RAF 1958 1:60,000	1:60,000	n/a	Block 4: D-6294	HSL for Sinclair
Quintana	N Somalia 3 blocks	RAF 1958 1:60,000	1:100,000	Area 1: 12 Area 2: 4 Area 3: 5	1: D-6446 2: D-6445 3: D-7536	HSL for Quintana
FAO	Inter-Riverine area not covered by others	Probably RAF 1958	1:60,000 1:100,000	73 42	60 k: D-5890 100 k: D-5896	HSL for FAO
Sinclair	Bur Region	HSL 1960	1:200,000	2	D-5473	HSL for Sinclair
Sinclair	Bur Region	HSL 1960	1:30,000	19	D-6430	HSL for Sinclair
Sinclair	Northern Somalia	HSL 1970	1:30,000	39	D-5738	HSL for Sinclair
n/a	East of Shabelle	n/a	1:100,000 1:60,000	6 6	100 k: D-6183 60 k: D-6476	HSL, likely for Sinclair
Continental Oil Co	North Somalia (within Block 3)	RAF 1958	1:200,000	20	Not applicable	HSL for Continental 1973
Tsetse Control Project 1980s	Inter-Riverine region	ASD Gmbh, Frankfurt (1983–84) 1:30,000	1:100,000	Not known	Not applicable	ASD Gmbh. No information on location

Sources RN Munro AP archives; NCAP, Edinburgh; Bodleian Library, Oxford; Paolo Paron

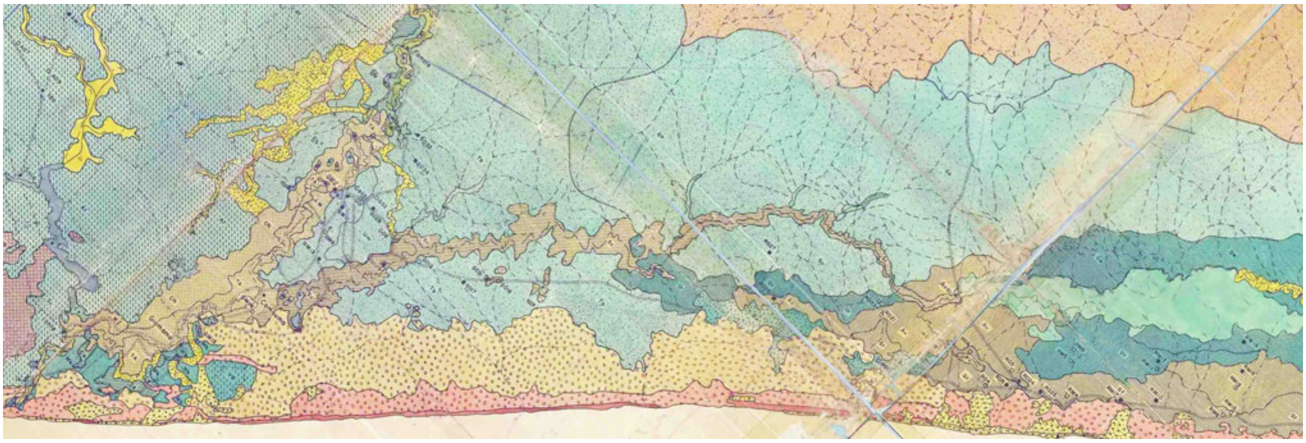

Fig. 14.4 Part of 1:500,000 scale soil map of Juba and Shabelle. Lockwood Landforms and Great Soil Group Map of Somali Republic. FAO Lockwood, 1968. *Archive Source* RNMunro. Also held at WOSSAC

Italians, they crossed first the Dry Juba, an old channel to the west, and then the Wet Juba at Jelib (Fig. 14.5), and in the campaign report commented: "The Juba's floods during the rains are famous. Far upstream, hundreds of miles from the sea, it is capable of drowning the country for miles around" (HMSO 1942).

Flooding, river bank breakages and general fluvial disruption remain common to this day: this is the role floodplains play, and human interference for cultivation or barrages restricts the floodplain. Also, the Dry Juba can still be wet in an unexpected way as we shall show from the 1981 floods study (Sect. 14.4). The economic assessment of Somalia (IBRD 1957) reported on the "extreme paucity of the natural resources, the severity of the environment and the limited extent to which it could be modified"; cropping in the *Gu* (April–May) and *Deyr* (October–November), major and minor rainy seasons, respectively, was always risky from drought. It was felt there were "few possibilities of modifying or of defying the severity of climate" and also noted that the "year ends with the long and punishing dry season—the Gilal". It appears that excessive floods are becoming more common than in 1980: analysis at Belet Weyne by FAO and SWALIM (Relief Web 2020 issued 26 May) showed that for the third year in succession floods

Fig. 14.5 Allied forces crossing the Juba near Gelib, February 1942. From HMSO (1942)

exceeded bank full level surpassing levels long regarded as a 50-year recurrence flood.

The World Bank (WB) agriculture sector study (World Bank 1980) had suggested, somewhat optimistically, that "Somalia is not, in fact, seriously water-short; it has adequate resources to supply its population and to sustain its major economic activities. However, water development in Somalia is expensive and must, therefore, be carefully planned and implemented". What was needed therefore was more coordinated assessments, a strong regulatory framework, land use planning to encompass all users and in general improved management of the land and water resources.

In modern times, a severe series of droughts affected the Horn of Africa and the Sahel region since 1968. Williams (2014a) has noted that an initial drought of 1968 in the Sahel was followed by dry pulses in 1971–73, 1977, 1982–84 and 1987, with another severe drought in 2005. From 1973 to 1975, much of Somalia was under the grip of a severe drought, and during 1974, farming and range conditions had deteriorated as both the *Gu* (April–May) and *Deyr* (October–November) rainfall seasons failed leading to 100% crop failure [see Chap. 2 for more detailed information about the climate of Somalia]. The World Bank (1977) Economic Assessment reported that the drought leading up to 1975 was more widespread and severe since the 1920s and resulted in up to 25% livestock mortality. Sinclair and Fryxell (1985) argued that the Sahelian drought, extending from Senegal through to Somalia, was man-made due to overgrazing and not lack of rain, and all exacerbated by piecemeal development projects. But, while this could have been the case in West Africa, over huge areas of land in Somalia and the Ogaden in adjacent Ethiopia, it was clear that the rains just failed. What water holes there were dried up, livestock populations were decimated and pastoral communities moved *en masse* to locations where the government with donor aid kept them alive and projects such as the planning for irrigation schemes gave hope to displaced peoples.

In contrast, a SWALIM study on preparation of disaster management plans in the Inter-Riverine (SWALIM 2016) recorded that river flooding occurs especially during El Niño conditions, with large floods noted in 1991/1992, 1994/1995, 1997/1998, 2002/2003, 2006/2007 and 2009/2010 periods.

14.3.2 Development Project Assessments in Southern Somalia

14.3.2.1 Physical Setting from the Inter-Riverine to Northern Somalia

East of the Juba and west the Shabelle is the Inter-Riverine of Somalia. From Beled Weyn to Sablaale, an active floodplain is incised into a series of older meander belts, levees and cover floodplains. Below Sablaale, the Shabelle swamps extend to the Juba confluence. To the north, the land rises up gradually as a complex of bedrock pediplains, basement rock inselbergs around Bur, and recent and older alluvial surfaces are dissected by ephemeral streams. Centred on Baidoa, the elevated Bay Region is formed on a thick pile of uplifted Mesozoic calcareous and gypsiferous marine sediments. As the Afro-Arabian dome was uplifted in the late Neogene and Pleistocene, the Shabelle and Juba Rivers cut entrenched courses into these Mesozoic rocks and, as revealed by offshore drilling, deposited large volumes of sediment into the Indian Ocean. Sediments were transported by the Tana River in Kenya to the Indian Ocean also and will have moved north-eastwards by the Somali current. The southward and seaward boundary of the Inter-Riverine zone nowadays is the coastal sand ridge, the so-called Old Red Sandridge (ORS), comprising stabilised and modern active aeolian dunes, that overly a coral and beach rock base over which sit the dunes. From gully sections at Brava examined by RNM in 1985, the ORS is shown to have numerous paleosol layers and a rubefied nature, as well as active dunes derived from rainfed erosion of the sands and onshore dune establishment.

A full chronology of the ancient dunes of the Somali coast remains to be laid out; evidence from coastal sequences in Kenya correlated by Braithwaite (1984) suggests dune sediments from the late Pliocene to Lower Pleistocene, and Somalia is likely to be similar. Age determinations and their meaning in relation to sea levels and Marine Isotope Stages are discussed below in Sect. 14.7 of this chapter. As the ORS is built up, it would have formed a barrier along the coast and the Shabelle would have connected to the Juba. The Shabelle is now confined in this trough, swampy at the distal end and only reaching the Juba, some 1080 river kms downstream from Beled Weyne, when there are large floods.

Bordering the right bank of the lower Shabelle and west of the lower Juba and over the border with Kenya are the so-called Marine Plain lands (FAO-Lockwood 1968), comprising heavy clays with high surface and subsurface sodicity (Solodised Solonetz soils) and also high salinity (Solonchak soils). These were regarded by Lockwood (1968) and HTS (1978a) as ancient lagoonal sediments, but while close to sea level, and taking into account regional uplift, this may well have been their origin as freshwater lagoons with seasonal saline influxes from the ocean perhaps, at higher elevations they represent alluvium derived from volcanic rocks within Ethiopia and Kenya. The Marine Plain lands do not receive run-off from the Juba and had long been considered too expensive to reclaim and only useful for rangeland and wildlife: they remain much thus.

The relatively fertile nature of the alluvial soils of the Juba and Shabelle floodplains was well documented on several studies (FAO-Lockwood 1968; HTS 1969, 1977a, b, 1979; MMP 1978a, 1978b, 1979), but development of lands for irrigation and rainfed farming would require farm management expertise in land reclamation to reduce moderate salinity—and locally some sodicity on levee soils—and improve drainage and tillage issues for heavy clays. Land suitability evaluation in those soil surveys showed that the older the landform, the more limitations were present. For example, in the Janaale-Bulo Marerta area (MMP 1978a, b—Genale–Bulo Marerta Annex I: Soils), the older Shabelle alluvium was given a class 3 suitability with permanent limitations of drainability, profile characteristics and salinity; the semi-recent and recent alluvium was predominantly of suitability class 2 with the same limiting factors with lower threshold values.

Along the course of the Shabelle in Somalia, groundwater that is suitable for irrigation and domestic use is restricted to the present and subsurface connected recent courses of the river and their environs. Beyond these areas, groundwater salinity increases rapidly as effects of direct recharge from annual floods diminish, and there are higher salinity groundwaters derived from bedrock evaporite deposits (MMP 1978a, b—Genale–Bulo Marerta Annex II: Water Resources).

The regional groundwater survey made as part of the Livestock Sector Review and Project Identification (HTS and GRM 1976) with map at 1: 2 million scale summarised the groundwater conditions over all Somalia:

- Hargeisa to Berbera: groundwater is limited to the alluvial wadi aquifers and some fractured metamorphic and karstic rocks;
- Hargeisa to Burao: alluvial and colluvial sediments of Burao basin with deep water of adequate quality in the Yesomma Sandstone;
- Burao to Belet Weyn: extensive area underlain by evaporite deposits. More reliable water supplies occur in karstic rocks;
- Shebelli Valley: groundwater quality along the upper Shebelli is poor but should be adequate for stock watering;
- Inter-Riverine area: groundwater occurs in several aquifers, namely the coastal dunes, Shebelli alluvium, weathered Bur Akaba basement complex and Mesozoic sedimentary rocks;
- Juba Valley: alluvial aquifers border the river and provide adequate watering points along the length of the valley;
- Trans-Juba to Kenya border on the Marine Plains: there is widespread salinity in shallow groundwater in the aquifers in Pliocene to Recent alluvium.

On terms of irrigation possibilities from groundwater, a regional assessment by the United Nations (1989) stated: “the exploitation of the consolidated sub-artesian aquifers for irrigation purposes is considered unlikely. These formations have very poor transmissivity, and this means large drawdowns for small yields. The prospects are better with respect to supplying the people and their livestock, but the boreholes must be installed very efficiently if the desired output is to be obtained with an acceptable drawdown”.

The Juba River, that discharges to the Indian Ocean near Kismayu, has good quality water for irrigation but during localised storms the first flush from run-off within its catchment in Somalia is high in silt and total dissolved salts (MMP 1979, 1980). Collier (personal communication 2020) noted that in the 1970s, a visiting specialist to the Inter-Riverine studies was concerned that Juba water was high in salts and unsuitable for irrigation as its waters would salinise the alluvial soils. In fact, the salts come from dissolved gypsum washed off the gypsum outcrops at start of the *Gu* season especially. After the first flush gypsum, soluble salt levels are reduced. The gypsum content of flood waters, such as we noted in 1981 (see Fig. 14.9), will reduce any sodium (alkali) risk hazard in the alluvial soils.

East of the Shabelle and extending to the north-east are the drier Mudug Plains. Rangelands where resilient vegetation arcs are steadily replaced by sub-desert shrubs and grasslands. Further to the north-east in Northern Somalia, the land is dominated by the Haud dissected plateau, on Mesozoic and Cenozoic sediments, that rises to over 2000 m on the northern escarpment. Drainage on the plateau is all ephemeral and to the Indian Ocean. The Haud plateau, partly covered by vegetation arcs (see Sect. 14.8), is terminated at the north-facing escarpment, and there is a sharp descent to the arid coastal lowlands. The eastern part of the escarpment, comprising the Ogo Mountains and Galgodon Highlands, has a mean peak height of 2450 m and is well vegetated as the high grounds catch NE monsoon rains and mist (Sect. 7.2). The western parts of the plateau in Somalia, between Borama and Hargeisa, lie at around 1400 m asl, and the escarpment is less abrupt. Ephemeral streams drain to both the Indian Ocean, mostly through the Nogal Valley some 150 km west of Qardho (Sect. 14.7), and the Gulf of Aden, such as for the Arabsiyo Valley (Sect. 8.2). In the extreme north, raised marine terraces were described by Brook et al. (1996): the highest terrace at 16 m above modern sea level did not provide any datable material, but based on other sites in the region was likely to represent MIS 5e at 132–120 kyr BP. Lower down a terrace at 8 m above sea level was dated at 105 kyr BP (MIS 5c) and a 2 m terrace at 80 kyr BP during MIS 5a. Following the post-glacial transgression, it was considered that sea level was close to its present position by the middle Holocene, at 7 kyr BP.

14.3.2.2 Development Projects

In the 1960s and 70 s, the rangelands, both in the north and also east of the Shabelle, were drought stricken and pastoral nomads lost all their herds. From the late 1960s through to late 1980s, numerous feasibility studies were initiated for irrigation on the main rivers, rehabilitation of rangelands and for rainfed agriculture. Assessments of the livestock situation were made in 1978 by HTS and Gunn Rural Management (GRM), while Murray Watson of Resource Management and Research (RMR) made airborne surveys of livestock and wildlife based on ecological strata (Watson et al. 1979; Watson 1982, Watson and Nimmo 1985). We draw attention to but do not make assessments of these studies, nor for other rangeland projects and studies made in Somalia since the 1960s (e.g. FAO 1980; Hemming 1966, 1971; Le Houérou 1972; Iannelli 1984; Pratt 1972; World Bank 1979; IUCN 2000). We can comment briefly on the National Tsetse and Trypanosomiasis Control Project (NTTCP) that was funded by the United Kingdom's Overseas Development Authority (ODA) during the1980s in the middle and lower Shabelle and aimed to eradicate along the Shabelle the host and its disease. After a planning phase (Bourn 1977), the tsetse control project ran from 1985 to 89 implemented by HTS and Agricair of Zimbabwe. The project has been reported by MMP (1983), Hendy (1985), HTS (1988) and others. The project adopted aerial spraying (Lee 1969), with endosulfan sprayed onto infected areas. Tsetse fly traps were used to monitor results but most were stolen. Many of the project documents are held at the WOSSAC archive, and a more multidisciplinary assessment could reveal much concerning its impact.

In the late 1970s, a large migration of displaced people had moved to the Shabelle and Juba Rivers from traditional grazing areas that had become too dry to sustain any livelihood. Many came from the Ogaden. East of the Shabelle River, in the Central Rangelands area, some 600,000 people were affected, and there were major losses to crops and livestock. To overcome food shortages, 20 relief camps were established, and by 1975, as conditions improved, the government decided to close the camps and resettle people at a number of agricultural and fishery schemes in the south of the country, between the two rivers. These were at Dujuma, Sablaale and Kurten Waarey, and by mid-1975, some 245,000 had been resettled at these schemes, mostly former nomadic livestock owners whose herds had been depleted. It was recognised though that the schemes had specific problems relating to the availability of cultivable land and also irrigation water, and World Bank missions to Somalia in May and July 1975 recommended that future resettlement programmes needed to be based on a sound technical and economic base for rural development: this was the *Inter-Riverine Agricultural Study* (the IRAS), placed within the Somali Government's Settlement Development Agency (HTS 1977a). The study started in mid-1975 and covered the lands between the Shabelle and Juba Rivers, some 200,000 km^2 in all. IRAS provided a comprehensive assessment of previous natural resources and socio-economic data; assessed the water resources of the Juba and Shabelle basins including a review of the hydrogeology of all Somalia; assessed the potential for dryland agriculture irrigation in this region; and determined the suitability of the soils at the three settlements and other areas that might be identified. Extensive soil studies were made along the Juba River for the Fanoole Settlement project (HTS 1978), where a state sugar farm was later established. The Dujuma area survey, made for the Settlement Development Agency, found the soils were on old alluvium partly of non-Juba origin, were derived from adjacent terrains and having variably high salinity and moderate sodicity, and were regarded as not suitable either for investments in irrigation or rainfed cropping (HTS 1977b). This honest appraisal was accepted and became, for Somali specialists anyway, a classic example of the value of making soil surveys prior to implementing development! The Soil Atlas of Africa (Jones et al. 2013) confirms that the soils on the gently rising plains bordering the Juba, that include the Marine Plain soils noted above, are variably saline and sodic.

The IRAS project produced two maps at 1:500,000 scale showing the locations of some 78 Existing and Proposed Development Schemes up to 1977. Parts from sheet 3B (WOSSAC ref 7132) are shown in Figs. 14.6 and 14.7, with selected projects listed in Table 14.2. These maps—perhaps the most useful starting point for new studies to look back at —are held at WOSSAC since 2008 and long before that available from HTS, but remain un-digitised.

Post-IRAS, a series of development projects were made along the Juba and Shabelle plains. These examined lands for soils, irrigation and agriculture for the Fanoole reach on the Juba (HTS 1978), and at Genale-Bulo Marerta (MMP 1978a) and Homboy (HTS 1979) on the Shabelle. Subsequently, the Genale scheme was partly developed, but Homboy was not initiated (SWALIM Report W-05: Mbara et al. 2007). At Jowhar, the problems of drainage and reclamation were intensively studied (MMP 1978b) prior to the development of the Jowhar Off-stream Storage Reservoir. On the uplands between the Juba and Shabelle, the World Bank gave support to the Bay Region Agricultural Development Project (BRADP) assessed by HTS (1982, 1983). Due to lack of older oblique photography for repeating, the status of BRADP is not covered in this paper.

Fig. 14.6 Development studies status as at 1977. Shabelle: Balad to Mahaddei Weyn reach. From Sheet 3B, Inter-Riverine Study, HTS, 1977a, b. Selected projects listed in Table 14.2. *Source* RNM Somalia archives. Also held at WOSSAC Ref 7132

These are the older studies that for the most were available to us in our Inter-Riverine projects made 1980–86 and re-examined in the following sections of this chapter.

14.4 Case Study: Irrigation Designs at Luuq and Jalalaqsi

14.4.1 Background

In 1980, RN Munro was part of the MMP/HTS team making irrigation project plans for the UNHCR at Jalalaqsi on the Shabelle, and Luuq on the Juba, where there was a need to develop permanent agriculture based on irrigation for the large numbers of displaced nomads from the Somalia and Ethiopian Ogaden (MMP 1980). We look at what was proposed and the situation now.

14.4.2 Juba at Luuq

On the Juba River, the reconnaissance survey concluded that the Halba plains on the right bank should be assessed further to a pre-feasibility level of irrigation design. Aerial photography available to the team in 1980 was limited to a 1960 Spartan negatives, made from 1959 to 60 AP. The scanned negative mosaic (Fig. 14.8a), part of a set of the whole Juba donated recently to NCAP, shows the landscape then. We found a previous irrigation system had been installed on the Halba plain, at some date after the 1959 image was taken, but was defunct in 1980. A Google Earth image dated 7 February 2015 (Fig. 14.8a) shows that almost all the forest lands around Luuq and along the Juba have disappeared, likely cut down by the refugees in early 1980s. One can observe that on the alluvial floodplain, forest is now mostly occupied by strips of pump-irrigated lands. These small-scale irrigation farms will be inundated at times of high floods, but pumps can be removed. A larger pump station, such as proposed for Halba, could probably be inundated and lost. Some forests remain upstream, seen at extreme right in the Google Earth © image.

A cross section of the soils at Halba made on this study identified a trough with a deep fill of old alluvial clays (Fig. 14.9). The Dolo series clay soil (Lockwood-FAO 1968) is seen as the dark red linear patches in the Google image (Fig. 14.8b). The Dolo clay surface soil passed down into >5 m of clayey alluvium, and we concluded it was likely a relict Juba channel infill: its highest part is 4 m above present maximum flood level, and the old channel was estimated to extend down to the level of the present Juba River bed. There are other similar linear patches of alluvium on the plateau on both banks, suggesting an anastomosed river. The alluvium-filled troughs were cut into the Main Gypsum Formation (Merla et al. 1979). The adjacent lands

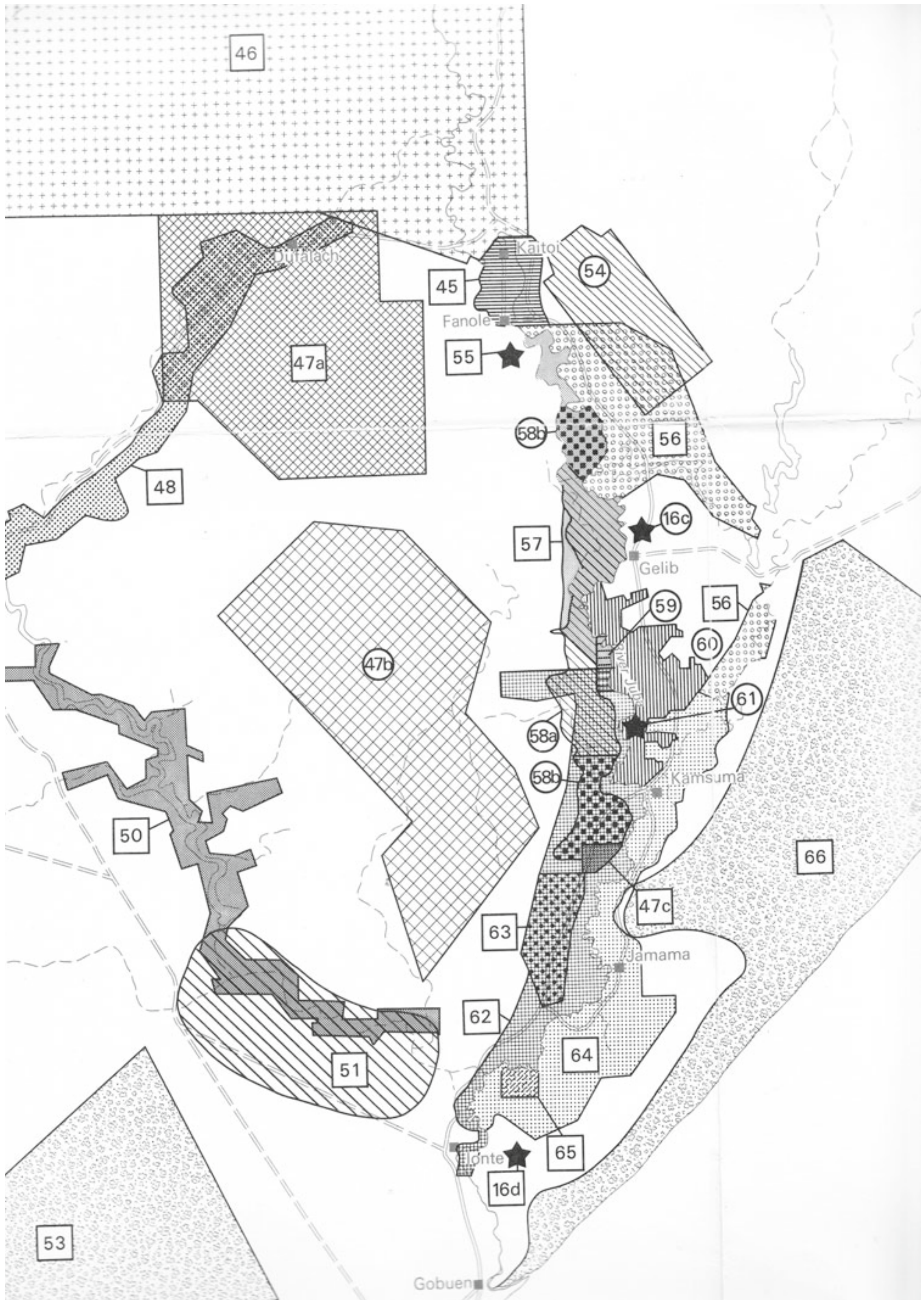

Fig. 14.7 Development studies status as at 1977. Juba: Fanoole to Gobuen. From Sheet 3B, Inter-Riverine Study, HTS, 1977a, b. Selected projects listed in Table 14.2. *Source* RNM Somalia archives. Also held at WOSSAC Ref 7132

beside the Juba are all highly gypsiferous (>70%); the ground in fact is riddled with cavities and gypsum karst sinkholes. The MMP study noted that gypsum was common in all the soils, and care would be needed when designing structures that would not collapse if gypsum was dissolved by irrigation waters.

Later, vegetation and soil studies were made at Luuq by a charity, Inter-Church Response (IRR) (Wieland, 1983; Wieland and Werger 1985) to assess ecological change due to refugee influx. This could be a useful study to re-examine the vegetation and any ecological change in the future. The IRR study referenced the MMP (1980) study somewhat absurdly as "Anonymous", but made no mention of the study in the text. However, they stated that the Dolo clay soils lay on a higher terrace of the Juba, which agreed with our 1980 findings.

In 1986–88, a USAID-funded team made a comprehensive environmental assessment (EA) of the Baardheere Dam Project on the Juba upstream of the proposed Baardheere Dam (Brandt and Gresham 1989; Brandt 2000). In terms of

Table 14.2 Key projects shown on Figs. 14.6 and 14.7

Number on	Name and extent	Reference
6	Johar Experimental Rice Farm 100 ha	Agric Res. Institute. See HTS, 1977a, b
7	Burei, Johar Experimental Sugar Farm. 100 ha	Govt. See HTS 1977a, b
8	Johar Sugar Estate, net potential 8300 ha	Govt
9	Johar Drainage and Reclamation Study	MMP/HTS 1975
10	Johar Crash Programme Farm. 230 ha	See HTS, 1977a, b
11	Johar Off-stream Storage Reservoir. 11,000 ha	HTS/MMP, 1969; MMP, 1973
12	FAO Livestock Fattening Project. 14,500 ha	See HTS, 1977a, b
13	Balad Controlled Irrigation Project. 1000 ha in 1977	HTS/MMP,1969
14	Balad Irrigated Feedlot (M.L.F.R.). 400 ha	See HTS, 1977a, b
15	Warmahan Fodder Farm (M.L.F.R.). 3800 ha	See HTS, 1977a, b
46	Dujuma National Park. 380,000 ha	Technital, 1975
47a and 47b	Trans-Juba Livestock Project. 160,000 ha	See HTS, 1977a, b
51	Descek Uamo National Park. 40,000 ha	Govt
53	Forest Reserve. 140,000 ha	Abel and Kille, 1976
54	Gelib Livestock Holding Ground. 21,500 ha	Govt, and EDF
56	Fanole-Gelib Irrigation District 6. Net area 26,400 ha	See HTS, 1977a, b
58a and 58b	Lower Juba Sugar Project. 23,900 ha	Booker McConnell, 1976—reports now at WOSSAC
59	Kalanji Banana Farm, Pilot 250 ha	National Banana Board. See HTS, 1977a, b
62	Ionte Irrigation District 32,000 ha	Govt. See HTS 1977a, b
63	Mogambo Irrigation Project. 7000	TAMS/FINTEC, 1977; MMP, 1979
64	Jamame Irrigation district. 20,050 ha	Govt. See HTS 1977a, b
65	Torda Irrigation Project. 2400 ha	Govt. See HTS 1977a, b

archaeology, the EA discovered 686 sites within the 420 km^2 of the proposed reservoir; the oldest sites were Middle Stone Age (ca 280–25 ka BP) and included Neolithic rock art cave sites and early Islamic cairns and graves. Geomorphologist Martin Williams found that there were no high terraces in the Juba Valley such as they are commonly found in semi-arid terrains within the Horn of Africa, and there was only clayey alluvium—slack water deposits—in side valleys and low-lying areas (Williams 1995, 2014b, 2016). This accords with our explanation of the clay-rich Dolo soil and alluvial fill found in the Halba area (Fig. 14.9). He found that both paleo- and contemporary floods leak rapidly into the surrounding karstic terrains, and that a dam at Baardheere would never reach full supply level in such limestone karst country. Ali Kasim et al. (2002) also noted the lack of any high terrace on the Juba in this area.

Additionally, Williams (2014b) noted the reservoir would flood all the fertile alluvial lands up to Luuq and destroy the farming livelihoods of thousands of people, as there was almost no soil on the higher grounds—a common result of dams proposed or built on rivers such as the Main Nile in Sudan and upper Egypt that pass through rocky deserts with a narrow and extremely fertile floodplain. Also, from gastropod shell evidence in Holocene alluvium, it was clear that the two main vectors of Schistosomiasis could lead to this parasitic disease becoming endemic in the reservoir and all along Juba Valley.

Another factor that we noted in 1981 on the flood study, and confirmed on the 1:2 million scale Hydrogeology Map of Somalia (HTS 1976), was that directly at the proposed dam site the bedrock comprised a 10-km-wide outcrop of gypsiferous marls and clays of the Warendab (also called Anole) Formation (HTS 1976; Merla et al. 1979; Abbate et al. 1994).

Before the USAID EA study, the feasibility study made by Technital (1975) had stated a future reservoir would be "watertight": it would appear that it would not have been so.

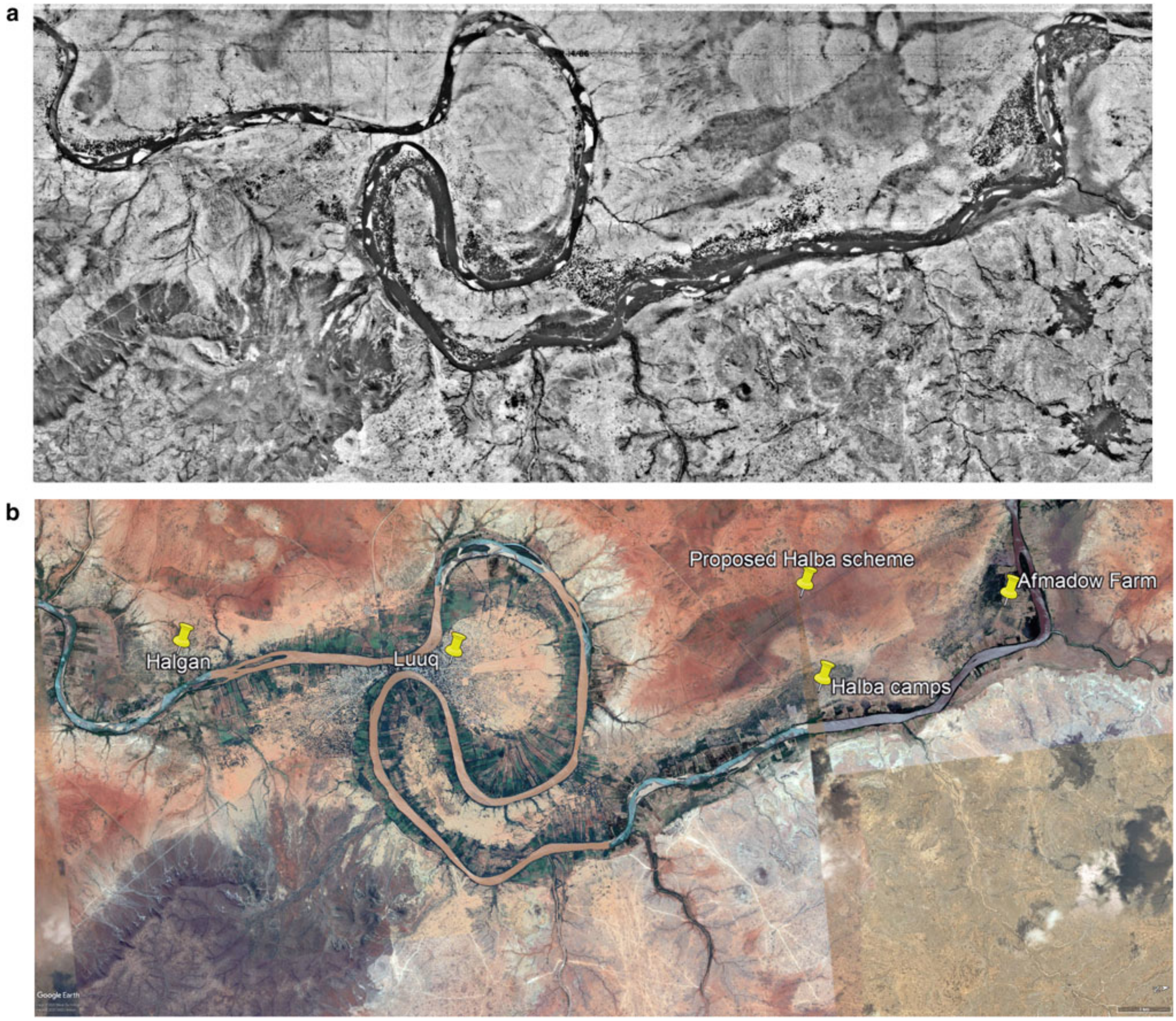

Fig. 14.8 **a** Luuq, 1959. Luuq Area. Sheet D7/C7 of Spartan Negative made in 1960. From former HSL archives donated by RN Munro to NCAP in 2019. Negatives © NCAP. **b** Luuq, February 2015. The Juba flows to the left. Pale tones of gypsiferous bedrock. The Halba area where irrigation was designed is shown to right of meander loop. Google Earth ©

Further, the World Bank's 1981 agriculture sector review (World Bank 1980) stated that "*the Baardheere Dam does not look like an attractive investment in relative terms*". Following the EA, the World Bank agreed to the next phases of the EA in this area and to evaluate the significance of prehistoric/historic sites, conduct excavations and prepare a full Cultural Heritage Management plan. Civil war put a stop to any further work. However, the implications of building a dam on limestone and gypsum karst terrains, the socio-economic factors relating to loss of livelihoods, the loss of known cultural heritage and the likely spread of Schistosomiasis weigh heavily against any future plans for approval of an investment design for a dam at Baardheere. That it all was taken so far towards a final acceptance in the past seems to indicate geopolitical overriding of environmental and cultural heritage concerns.

The Halba scheme that MacDonald's designed to pre-feasibility level in 1980 was not initiated. Google images show canal lines that have not been connected to the Juba for a long time, if ever; the dark red deep clay soils are utilised for rainfed farming only and are partly covered by secondary bush and termitaria. Collectively, the irrigation strips cover far more land than the proposed Halba scheme and are nourished most years by silt-laden floods.

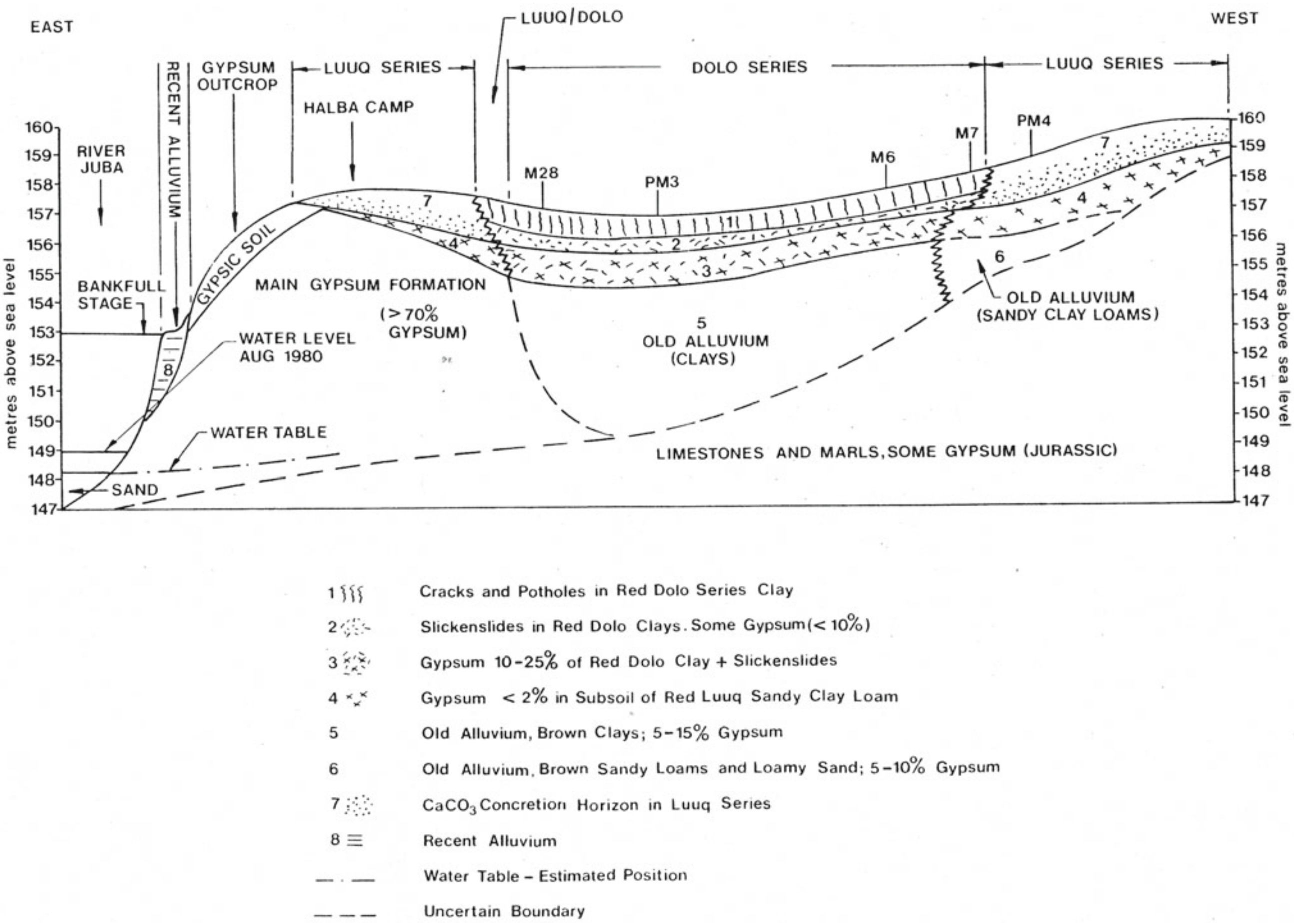

Fig. 14.9 Soils cross section—Halba area. From MMP (1980). *Author* Munro

14.4.3 Shabelle at Jalalaqsi

The Jalalaqsi studies in 1980 were made on the right bank of the Shabelle downstream of Jalalaqsi, on old Shabelle River alluvium. In Fig. 14.10a, an aerial photograph from 1960, Jalalaqsi is at top left, and the pre-feasibility study area lies downstream of the town at far right. Examination of the area now using Google Earth imagery (Fig. 14.10b) shows that various inlet canals extend to east from the Shabelle, and irrigation canals have been laid out to supply fields. These do not look as if they were in use at time of the imagery (24 January 2014). A meander loop downstream of the newer pump station has been cut off since 1960. As refugees moved back to the Ogaden areas, the need for a larger scheme became redundant. There is however considerable small-scale irrigation along the Shabelle alluvial floodplain using portable pumps that can be removed at times of floods. The Jalalaqsi scheme designed to pre-feasibility level in 1981 was never taken to a detailed design level. Google images show several canal lines from the Shabelle but most appears to be rainfed agriculture. Irrigation, as at Lugh on the Juba, is restricted to small-scale pump schemes using alluvium of the floodplain.

The 1980 soil studies, summarised in a cross section (Fig. 14.11), were guided by the Lockwood-FAO (1968) and Inter-Riverine study (HTS 1977a, b). Subsurface gypsum concentrations up to 70% were found in the subsoils, derived it is thought from gypsum-rich groundwaters, and raised a concern when designing engineering structures that could collapse from solution of gypsum: the land suitability classification took this into account.

14.4.4 Conclusions

The schemes designed to pre-feasibility level at Jalalaqsi and Luuq were never taken further by UNHCR: the refugee crisis was downgraded and people returned into the Ethiopian Ogaden. Also, by the mid-1980s there was a period of more favourable rainfall. In 1981, the Agriculture Sector Review (World Bank 1980) concluded that the approach to drought proofing that emphasised resettlement of nomads and

a

b

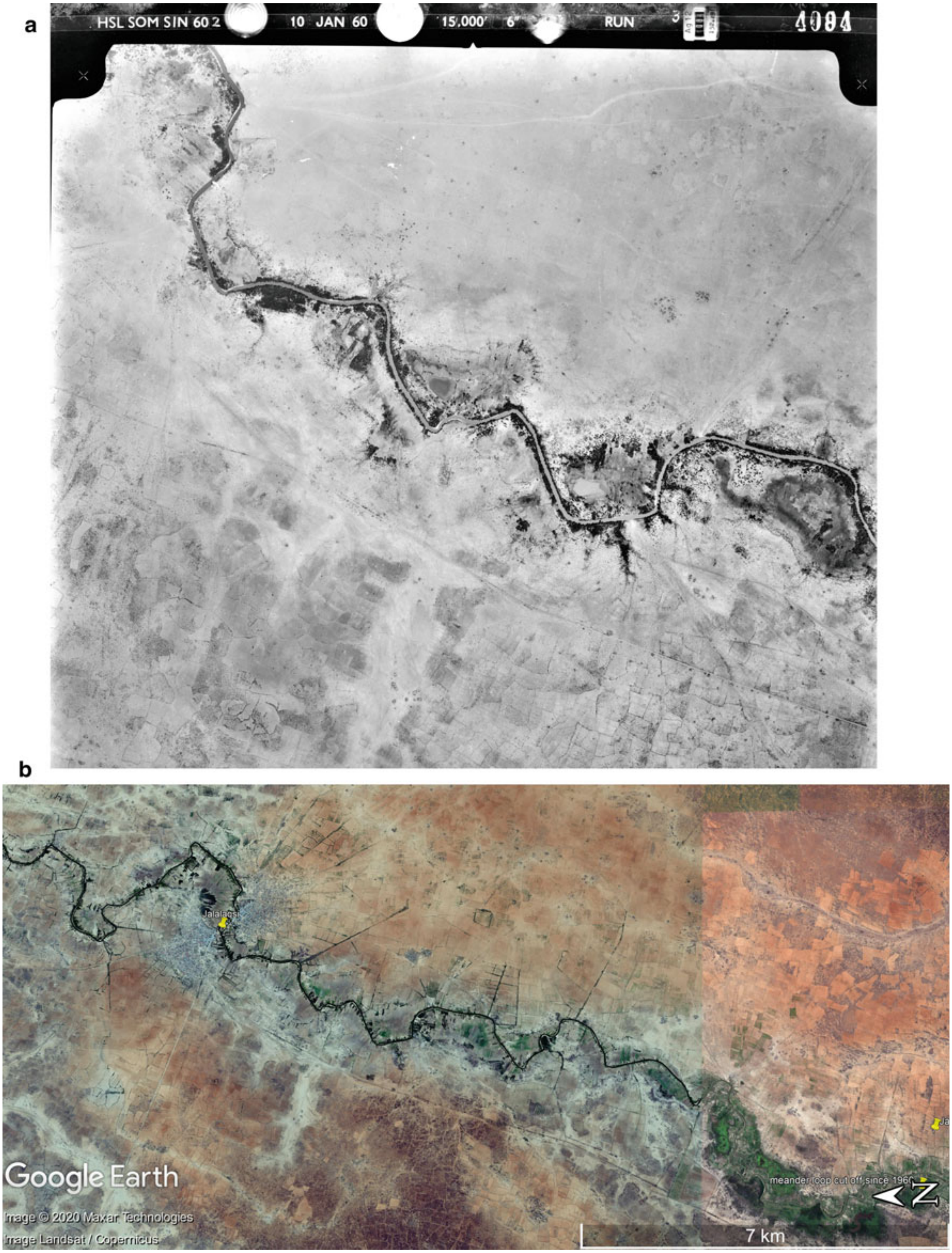

Fig. 14.10 **a** Jalalaqsi is the small settlement with a road bridge at top left. HSL 1:30,000 AP flown 10 January 1960. From RNM photo archives to be donated to NCAP. **b** Jalalaqsi Area today: Some irrigation layouts and pump stations on older alluvial plains. Google Earth 2014 and 2017. Google Earth ©

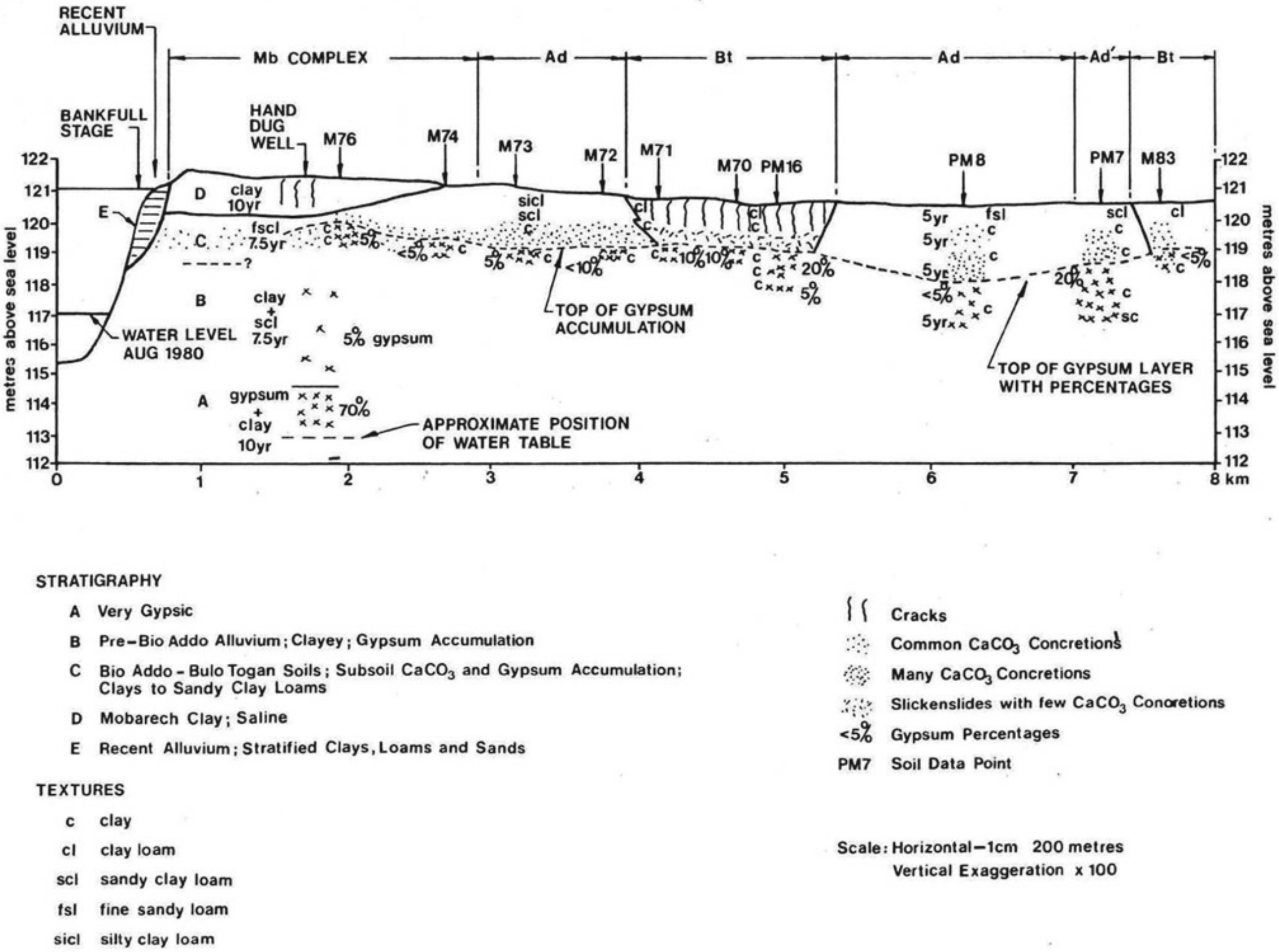

Fig. 14.11 Soils cross section—Jalalaqsi Area. From MMP (1980). *Author* Munro

horizontal expansion of irrigated agriculture was: "judging from the results to date, not the right approach to resettling nomads under Somali conditions, and that the settlement programme, started in 1975, had not succeeded in achieving its objectives of creating self-sustaining communities for former nomads".

However, while the modest schemes that were planned did not materialise on the higher terraces along the Juba and Shabelle, the resulting decades have seen a huge increase in the employment of pumps to irrigate small-scale schemes along both rivers utilising the fertile alluvial lands. These have benefitted many thousands of small holders, and given the success of early warning systems transmitted down to the communities by social media, pumps can be removed easily at times of floods up onto higher ground. Some larger fixed pump stations exist at key places and take water onto the higher elevations: these are more vulnerable if and when a major flood occurs. Rehabilitation of the larger schemes, for example Jowhar and Juba Sugar schemes, awaits a more secure period.

The IRAS project maps at 1:500,000 scale showing the locations of some 78 "Existing and Proposed Development Schemes" are due for an update with a review of the status of the older projects, but access to many areas will remain very difficult at this time.

14.5 Case Study: Flood Damage Study of the Juba and Shabelle Inter-Riverine

14.5.1 Background

In April and May 1981, huge floods swept down the Shabelle and Juba from Ethiopia, impacting heavily on the alluvial lands of the Inter-Riverine area. Locally, high rainfall compounded the disaster.

It is a region that has always suffered from either too much or too little rainfall and either damaging floods or insufficient irrigation water in the two rivers. Successive appraisal reports by UNOCHA now indicate that the *Gu* or

Deyr rains look promising but then later have to report crop failure is possible. SWALIM has archived numerous such similar reports over the past ten years. In 2019, heavy rainfall in the upper catchments of the Juba and Shabelle led to high discharges with floods in Somalia and reported on breakages in the rivers with flooding into back-swamps or old channels, and there is an active early warning system that delivers information on floods and damages to decision-makers and aid agencies. There is little new in these contrasting events in 1981 or 2019 as the hydrology records show.

In 1981, the Somali authorities made their own damage assessment and with FAO requested a detailed engineering (MacDonald's) and agricultural (Hunting's) consultancy to examine all aspects: Mark Brett and Munro, Engineer and Geographer, respectively, mobilised rapidly in mid-June for the FAO Flood Damage Study. It sounds an apocryphal tale, but was true, that in early 1981 an FAO drought assessment mission was mobilised some months earlier than the Flood Damage Study. The former, we were told, took a while to mobilise, and their arrival coincided with the rains and floods, so they had no option but to depart immediately. To us this summed up the rather unpredictable Somalia situation of drought or flood.

The team had use of a 1970 map made from aerial reconnaissance by MMP of the June 1970 Shabelle River floods that covered a huge area of the Shabelle—lower Juba area (MMP 1970) with cross-country floods utilising both old Shabelle channels and back-swamps. In 1981, floods and heavy rainfall had also covered the region. During May and June 1981, FAO hydrologist Brian Gemmell had made a number of flights, drawn preliminary flood maps, and commenced to repair the largely destroyed network of flood level indicators and gauges.

14.5.2 Remote Sensing Methods

FAO Rome had worked at high level with NASA to acquire recent 14 Landsat scenes of the area. Despite the close cooperation, the images arrived after fieldwork ended and while of great interest were of marginal use due to the low resolution of the MSS imagery, the extensive cloud cover and acquisition dates in May and June well after the flood peaks. FAO recognised this as an important test case to acquire imagery rapidly and get it to the people in the field. NASA could not deliver the imagery while the mission was in the field but FAO considered that it was a very useful exercise, and a lesson learnt for future policy; the images also helped us refine our maps back in the office. It is all very different nowadays where imagery is readily available within a short time from various satellite platforms.

On the mission, firstly we examined the flooded lands from the air in a twin-engine Cessna over three days (28–29–30 June) up and down both rivers. Then we made the same journey by car to examine the situation on the ground, where we could visit as flooding was still present over huge areas, and cost up the damages. On our flights, we used Gemmell's maps and marked up revisions of flood limits, as best one could at about 300 km/h. The base maps were the excellent Russian 1:200,000 topographical maps. These amalgamated lines were later redrawn onto fair copies of the maps, with boundaries augmented using the many oblique aerial photos taken by Munro. Four of the final maps for the Shabelle and Juba are shown. Each map is then followed by samples of the oblique shots. Normally, such flights are recommended to be made after a ground reconnaissance, when one knows the terrain intimately and can pinpoint features on maps more easily. Fortunately, RNM had made quite extensive ground journeys in 1980 that covered the Shabelle and Juba Rivers and the Baidoa area. The 1981 flights and motor tours more or less repeated the aerial excursions and showed clearly many interesting points that often would have been difficult to understand on the ground, if indeed access had been possible. The government had made its own study of costs of the floods, and these were compared with the MMP work. Four of the Shabelle and Juba flood maps from 1981 maps are given here and show the extent of the floods over parts of the Juba and Shabelle (Figs. 14.12, 14.13, 14.19 and 14.20).

14.5.3 Assessments on the Shabelle

The extent of the 1981 flooding downstream of the Ethiopian border and in the reaches to Jowhar Sugar Project are shown in Figs. 14.12 and 14.13. Gauge measurements on the Shabelle at the border showed that the flood exceeded 1000 m^3/s on 30 April, more than double of the previous record flood of 400 m^3/s. Inevitably, it covered the entire extent of the floodplain up to the dune ridges on the left bank. The Shabelle had flooded Bulo Barde, and breaches were made to reduce flooding in the town. Water flowed into an old back-swamp leaving an impressive crevasse splay feature (Fig. 14.14a) but had bypassed the flood-relief channel. By 2005, the flood-relief channel had been improved (Fig. 14.14b), and it takes excess flood off the Shabelle at Beled Weyne and then returning it to the river further downstream.

Further downstream, almost all back-swamp areas along the main course of the Shabelle were flooded, as one might expect. Most settlements were on the levees or the higher ground of the adjacent sandy plains that slope upwards away from the river, as this sort of flooding is frequent and acts swiftly.

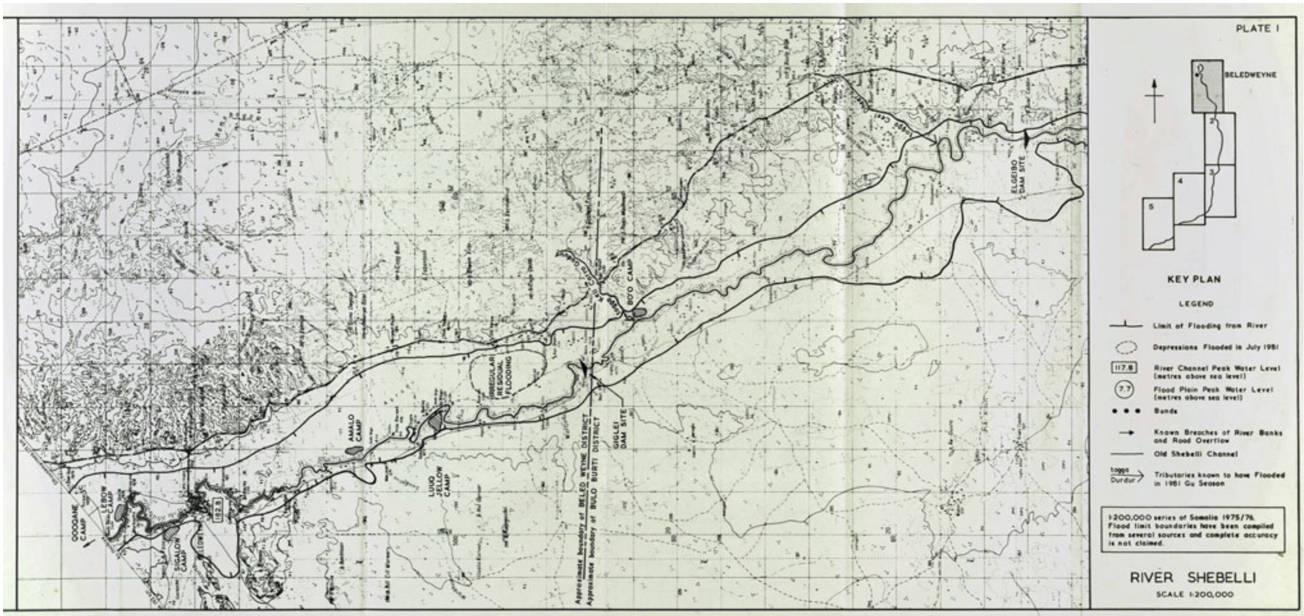

Fig. 14.12 Flood Damage Study Sheet 1: Shabelle from Ethiopian border to El Geibo (MMP 1981). Report held by WOSSAC

On the right bank, the floodplain of the Shabelle opens out just above Jalalaqsi, and there are numerous old meander belts and accompanying back-swamp depressions that extend south-west towards, eventually, the Juba (Fig. 14.15a). By 2017, much of the woodland/forest in this reach had been removed (Fig. 14.15b). Wanle Weyn on the road to Baidoa lies at the limit of the old mega-floodplain. A flood broke through at Dobale and entered one of these low-lying areas at Mahaddayweyne and then went cross-country in a south-west direction, broke through the Baidoa road, flooding the FAO Seed farm, and continued onwards, where, on 28 June, we photographed the margins of this by now quite slow-moving or even static flood—it was difficult to judge, of course, movement from the air (Figs. 14.16 a–b, Fig. 14.17).

Downstream, floods had entered part of the Jowhar sugar plantation, but flood channels worked well and most of the flood was channelled into the storage reservoir from the Sabun Barrage offtake (Fig. 14.18a). The Off-stream Storage Reservoir (MMP 1978b) lies on the Shabelle left bank at Jowhar, on old clay cover floodplains. The Jowhar irrigation project today is only working partially. The reservoir appears to have been functioning in recent past (Mbara et al. 2007), but a Google Earth image taken in 2019 shows limited irrigation activity in the plantation with the reservoir a large swamp (Fig. 14.18b).

Between Jowhar and Dobale, the study recommended that for future flood control the low-lying alluvial lands on the left bank east of Mahaddayweyne and the Sabun Barrage could be utilised as a flood-relief channel between the sugar plantation and the sand ridges. Recent Google Earth imagery shows that this linear depression has been utilised by flood waters in recent years and also that long embankments have been constructed across the valley and to the west of Mahaddayweyne, starting some 27 km downstream of Jalalaqsi and appear to be flood control measures to deflect floods into old channels and protect the main town. On the Shabelle left bank below Sabun, as seen on recent Google Earth imagery, farmlands previously irrigated have been inundated by floods, and swampy low-lying areas are fringed by wide belts of saline efflorescence in the soils.

Downstream of Jowhar and as the river flattens out, the Shabelle is flanked by a series of old channels, some with former meander belts quite clearly defined and others less so. In 1981, there was only limited flooding here all the way to the Shabelle swamps far downstream, and the *Gu* rains allowed rainfed farming to thrive that year: the common pattern of devastating floods next to undamaged lands where agriculture has a normal year.

14.5.4 Assessments on the Juba

On the Juba, the floodplain was filled by flood waters all the way from the Ethiopian border to Fanoole—Maps from the 1981 study are shown in Figs. 14.19 and 14.20. All rainfed or pump-irrigated annual crops on lower-lying lands were flooded and had mostly rotted by the time the flood receded. This was not unusual as the floodplain is narrow, and people were able to remove most pumps to higher ground. On higher grounds of levees, bananas often survived. Below Fanoole, the Juba Valley was constricted by flood protection

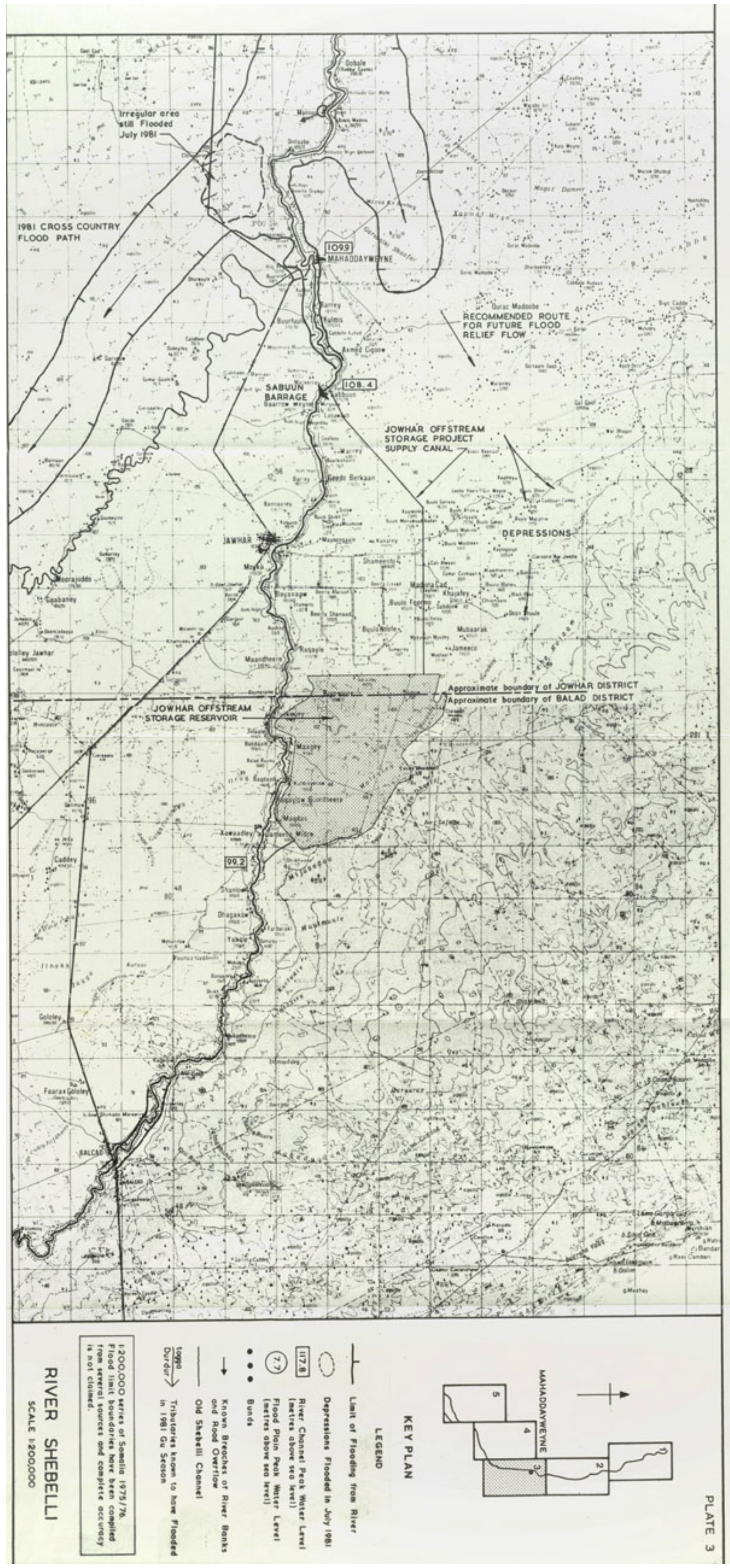

Fig. 14.13 Flood Damage Study Sheet 3: Shabelle from Mahaddayweyne to Balcad (MMP 1981). Report held by WOSSAC

a

b

Fig. 14.14 **a** Beled Weyn crevasse splay and flooding in the town, bypassing the flood-relief channel. Downstream is to right. *Photo* RN Munro ©, 28 June 1981. **b** Approximate same view generated from Google Earth ©. The town has expanded; the flood-relief channel had been constructed at the crevasse splay point before 2004 has an improved intake. It takes excess flood to re-enter the Shabelle 2.8 km to the south where an old channel network connects to the Shabelle, but the entire town is at risk from any future mega-flood. Google Earth ©

a

Fig. 14.15 **a** Shabelle, North of Jalalaqsi. View downstream. The 1981 cross-country flood visible at right background. *Photo* RN Munro ©. 28 June 1981. **b** Approximate same view using Google Earth © 4 March 2017. Most of the riverine forest, woodlands and scrublands on terrains at left (on stabilised relict sand dunes) have been degraded and enclosed

bunds around irrigation schemes, such as Fanoole, Juba Sugar and Mogambo, but the flood was able to overflow into the Far Shabelle, an old Juba channel to the west, and travelled for some 50 kms southwards (Fig. 14.21a, b). Then, and much to the project's surprise, the flood entered Juba Sugar on the west unprotected side via Scorpion Lake (Fig. 14.22a, b)—a case of the Scorpion's sting. The repeat images are 35 years apart.

The Somali Government reports suggested that the overflow was due to siltation of the Juba River but our mission discounted this. At Juba sugar, the flood came in, and through the plantation at such a pace though there was not time for stagnant conditions to develop, losses were modest. The old channels, clearly visible on archival aerial photography, satellite imagery, and also depicted on the Russian topographical maps, had been forgotten, but came back to life: this example of fluvial geomorphology in action was most interesting to observe from the air (see Chap. 13), and our study led to a better appreciation in government and the Juba Sugar Project that geomorphology should always be assessed. This right bank flood then continued southwards and came back onto the Juba floodplain near Bur Koy. The subsequent flood control on the Little Juba due to bund constrictions resulted in a concern by the Flood Damage Mission that long-lasting damage would occur to many of the huge mango trees along the Little Juba (Webi Yaro), since flood waters along it had been diverted back into the Juba at Kumbararee, thus leaving the Little Juba dry downstream from there. This would become a disaster for the hundreds of mature and very valuable mango trees along its banks that were already showing signs of drought stress. The Flood Damage Mission recommended that the blockage at Kumbararee be opened soonest, and it was: recent Google Earth imagery shows that the same mature mango trees, up to 50 m high, continue to thrive. A barrage on the Juba now uses the old channel as an emergency flood-relief conduit, and irrigated lands further downstream are protected, though the Juba Sugar factory and its project infrastructure was destroyed in the civil war period.

The Mogambo irrigation project, only partially functioning before (MMP 1979, 1987), was reported by Mbara et al. 2007 (SWALIM W-05) to be inactive. A mosaic of

Fig. 14.15 (continued)

Mogambo based on 1963 AP (Fig. 14.23a) can be compared with Google Imagery (Fig. 14.23b, dated January 2016). A close-up shows the main canal completely defunct, and the scheme remains only partly used by small-scale pump operations (Fig. 14.24).

Further south, two sets of repeats show the degradation of a fertile land: firstly, some 14 km SW of Jamaame (Fig. 14.25a, b) and secondly over a part of the Ionte Irrigation District flooded in June 1981 (Fig. 14.26a). The Ionte area lies some 20 km SW of Mogambo scheme, and the main road to Ionte and Kismayu is at the base of the photo. A more recent oblique image generated from Google Earth © dated 7 February 2011 (Fig. 14.26b) illustrates the general degradation of agricultural efficiency in this region: irrigated lands are only close to the Juba, and the riverine forest of 1981 is almost completely removed, while other parts are poorly drained, and terrains not irrigated are reverting to bush.

14.5.5 Conclusion

There remains much scope to rehabilitate the lands on both the Juba and Shabelle Rivers that were flooded in 1981 and of course often before and since. The FAO's 1981 Flood Damage Mission, by combining aerial survey with groundwork and seeking the geomorphological and hydrological explanations and an understanding of why, for example, one area was flooded and another was not, sets a useful standard and precedent for future flood monitoring and damage limitation in Somalia. Security issues in the Inter-Riverine make supporting fieldwork difficult, but it is hoped this will change.

One aspect the Flood Damage Mission noted was the accuracy of estimating the floods. The maps made by Gemmell, then revised by the Mission, and finally verified by ground observations, could be compared with the estimations in each district made by the Somali Flood Committee:

a

Fig. 14.16 **a** Cross-country flood at main road to north. *Photo* RN Munro ©, 28 June 1981. **b**. NEW Google Earth © 28 February 2013 imagery. The flood occupied the grey Vertisol soils of a former Shabelle back-swamp. Much of the bushland has disappeared and land is now more intensively cropped

- Shabelle. We estimated that out of a gross area of 128,000 ha flooded, some 26,000 ha was agricultural cropland. The official Somali Flood Committee assessed estimated 84,200 ha net.
- The cross-country flood covered 77,000 ha gross and 12,000 ha net. The Somali assessment underestimated at 2700 ha.
- Along the Juba, we estimated that out of a gross area of 144,000 ha gross flooded, some 53,650 ha was agricultural cropland. The official Somali Flood Committee Assessment estimated 66,952 ha net.

It is all much easier today with high-resolution imagery and cloud penetrating radar imagery that can be acquired quite quickly, and operational services/systems, such as the Copernicus Emergency Management Service (EMS) can provide in a few hours much of what the Flood Damage Mission took several weeks and flights by plane and long car journeys to complete. Security difficulties mean that sort of mission is not possible at the present. The EMS is a very useful service that uses imagery from earliest available suitable sensors and resolution be it Sentinel or very high resolution such as WV2 or 3, Pleiades and can provide detailed maps within 2–12 h for first estimate to damage grading assessment maps ready to print: all very more advanced than what was conceivable in 1981. In Somalia, where topographic maps exist at 1:100,000 scale, the infrastructure base could be in place before a flood event, and extent of floods depicted using freely available imagery such as Sentinel or Landsat, and then groundwork would need to follow up to assess crop and infrastructure damage: this is reported from districts. As it is, the assessments in Somalia reported by FAO-SWALIM (funded by UK Aid, USAID, World Bank, Somalia Humanitarian Fund, Swiss Confederation, Italian Cooperation, and EU) use for instance of WV2/WV3 Digital Global imagery that is readily available from archive. It is very useful to assess risk and plan emergency relief through reference and pre-disaster situation maps also available as EMS service:

[https://emergency.copernicus.eu/mapping/ems/emergency-management-service-mapping];

b

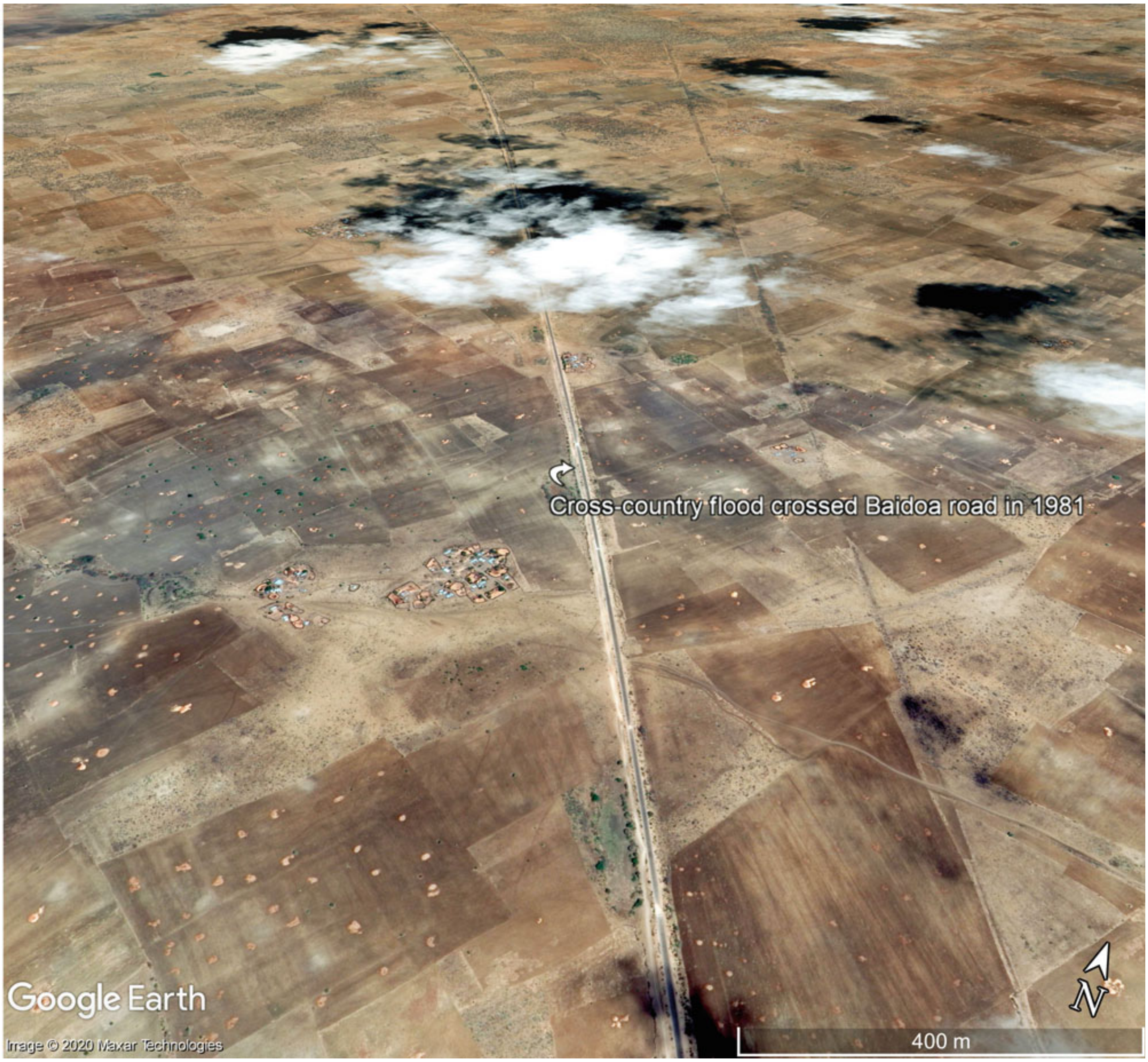

Fig. 14.16 (continued)

The assessment of such floods and their damage can be facilitated in part by rapid acquisition of imagery and change detection techniques to show, delineate and measure damaged areas. Hydrologic gauges and current metres on the rivers and routine establishment of rating curves are essential to maintain and are more robust and automatic compared to 1980s and no doubt will be in place for key stations already. In 1981, the gauges established by FAO (Gemmell 1982) following the 1981 floods were soon damaged or destroyed by floods in a following season. Civil war caused more damage, and a recent SWALIM study provided the status of many hydrologic stations and irrigation structures. Repair of structures and scheme rehabilitation in the Inter-Riverine will come with more peaceful times. The swamp maps made by Morgan and Thorn (MMP 1983) were based on the 1983 photography and could be re-examined to assess change. It would be useful also if more extensive use was made of the FAO model *Aquacrop* that uses real-time crop and climate data, together with soil, management and known groundwater conditions to predict the biomass and ultimately the yield of a calibrated crop. It should be in use as a tool.

In the future, it is likely that flood events will continue to cause losses to crops and infrastructure. With global change, these may well become much more frequent and more severe in destructive strength than hitherto. While dams on the

Fig. 14.17 Shabelle cross-country flood moving to the SW with its limit in distance. Difficult to repeat but about 15–20 km SW of the road crossing shown in Fig. 14.17a, b Illustrates the slightly uneven nature of the ground surface. *Photo* RN Munro ©, 28 June 1981

rivers could regulate floods, the investments needed are unlikely to be forthcoming, and the environmental and physical impacts are substantial. Better perhaps that a rethink is made of planning in the entire Inter-Riverine basin in view of these scenarios. One could, for example, abandon thoughts of rehabilitation of large schemes on the lower Juba and Shabelle and allow forests to return, biodiversity to recover; improve rainfed farming; and consider relocation to safer sites of frequently flooded major settlements on the Shabelle and Juba.

14.6 Case Study: Land Evaluation at Farjano

14.6.1 Background and Purpose of the Project

Improvements to the traditional rainfed agricultural sector in southern Somalia were initiated by Andrew MacPherson of Bingle Pty., who established rainfed schemes at Sablaale and Kurtun Waarey adjacent to the Shabelle River in the late 1970s (Citaco 1976; Bingle and Ltd. 1981–84; MacPherson 1983; World Bank 1984; Agrisystems Overseas Ltd 1984). Funded by the World Bank, the projects thrived. An advocate of rainfed farming over irrigation (as long as there is sufficient rainfall of course) MacPherson promoted rainfed farming for decades: on the clay belt rain lands of central Sudan, he considered that improvements in semi-mechanised rainfed farming—using precision levelling, opportunistic planting, improved cultivars, low tillage and good management (with farmers deciding on the spot rather than waiting for decisions from absentee landlords)—could be as productive as irrigation for numerous crops (Newtech-HTSPE 2008), and this has proved so.

On the sand ridge soils along the southern Somali coast, rainfed cropping gradually replaced woodland, but the soils were of low fertility. In 1984, Agrisystems, following assessments by GTZ (1982 1984) on the existing rainfed farms in the middle and lower Shabelle, made an appraisal report of the Farjano area for UNHCR. This proposed a rainfed scheme at Farjano, adjacent to Bingle's

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Fig. 14.18 **a** View upstream into Jowhar Sugar Project in background, with excess flood waters entering the Jowhar Off-stream Storage Reservoir. *Photo* RN Munro ©, 28 June 1981. **b** Jowhar Off-stream Storage Reservoir, 19 August 2019. Acting as a large swamp. The plantation above it has patchy cropping. Google Earth ©

semi-mechanised rainfed farming project Sablaale and next door to the Sablaale irrigated farm project that was initiated in 1976 by the Settlement Development Agency. The project commissioned by UNHCR was an intervention to assist the huge refugee problem in the mid-1980s and aimed to determine if the Bingle model could be applied there. The Farjano area was bordered on its north side by the Shabelle, by this point a rather feeble channel and on the south side by the rising ground of the aeolian sand ridge belt. The Farjano soils were on older Shabelle alluvium and generally free of salts or sodic conditions, and it was considered that if used carefully and utilising residual soil moisture, the lands could be developed using the moderate rainfall, though in drought years the soil moisture deficit would be critical for crops. Fieldwork was made by Munro during January and February 1985.

Figure 14.27 is an HSL print-lay-down mosaic constructed using 1958 RAF aerial photography, and it shows there was little development in this part of the lower Shabelle at that time. The Shabelle swamps lie on the left and right of this reach.

At the extreme right of the area, Abel and Kille (1976) proposed a Shabelle Swamp Wildlife Reserve. These swamps remain largely undeveloped. A study by Mostyn Morgan and David Thorn of MacDonald's (MMP 1983) for the UK Aid Tsetse control project (LRDC 1983; Hendy 1985) considered that the swampy terrains were very likely to be responsible for the more elevated rainfall in the lower Shabelle and thus should not be drained.

In the 1985 Farjano study, the author used the 1:30,000 AP from February 1983 (Table 14.1): this appears to have been lost and thus was not available for this review. The Farjano rainfed farming study examined the suitability of soils for rainfed agriculture, settlements, forestry and small-scale irrigation. The 1985 soil studies considered carefully the issue of residual moisture, as advocated by Whiteman (1975, 1984) elsewhere, and concluded it was feasible under careful management and using precise land levelling to reduce run-off. Further, it concluded:

– Settlement planning needs to consider that sandy soils on levees are most suitable for agriculture and the heavy

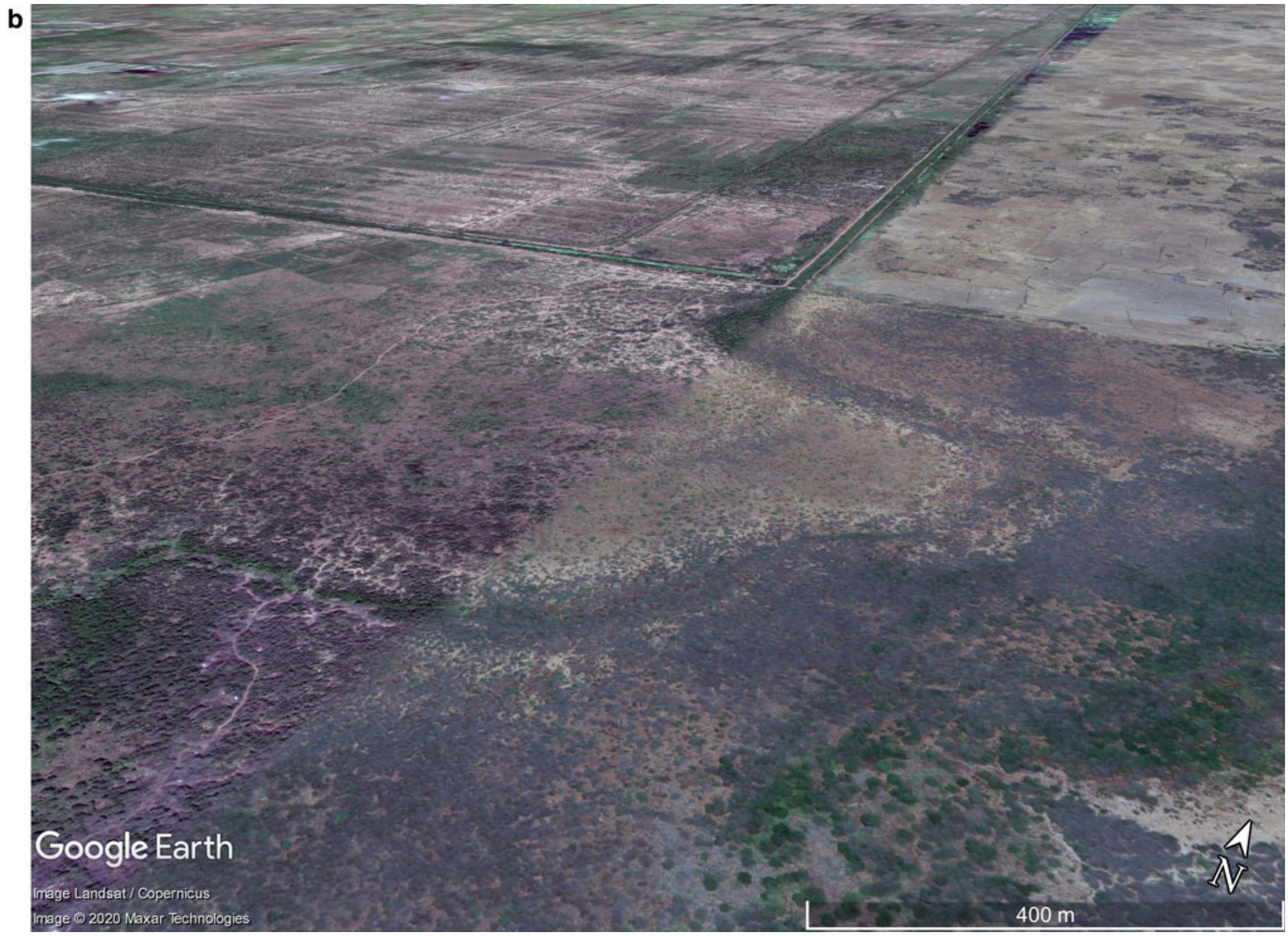

Fig. 14.18 (continued)

cracking nature of the Vertisol clays makes them the least suitable;

- For forestry, better coordination on research was suggested when choosing appropriate species;
- Rainfed farming will always be a risky business due the unpredictable nature of the rainfall.

14.6.2 Assessments and Present Situation

The situation now as seen on Google Earth indicates that the Farjano scheme remains under bush and the Sablaale rainfed farm has been converted to irrigated lands or returned to bushland with settlements within a wooded landscape. Figure 14.28 shows the rainfed farms in these changed conditions: the original irrigated farm at Sablaale remains active, and a large off-stream storage reservoir has been constructed in the Shabelle swamps to the north (dark green area at top of image). The main track from Sablaale to the coast cuts through the remains of the Sablaale semi-mechanised rainfed farm now reverting to bushland. At left centre is a former channel of the Shabelle with Chromic Vertisol soils and ground cover (in 1985) of *Sporobolus-Dactylococtinium-Achinochloa-Enteropogon* grassland and an invasive growth of *Acacia spp*. The lands on either side of the channel comprised mixed bushland of 4–5 m high *Securinega, Acacia, Lawsonia, Boscia, Dobera* and *Phyllanthus spp* on cover plains, also of Chromic Vertisols. This bushland appears to have been cleared completely yet the rainfed farm that we assessed and designed was not initiated. It is apparent that unreliability of the rains combined with onset of a civil war led to closing of the funded rainfed schemes. In an assessment of the rainfed schemes in Somalia, Rees et al. (1991) concluded that while reasonable Gu season maize production can be achieved in most years, fallow soil

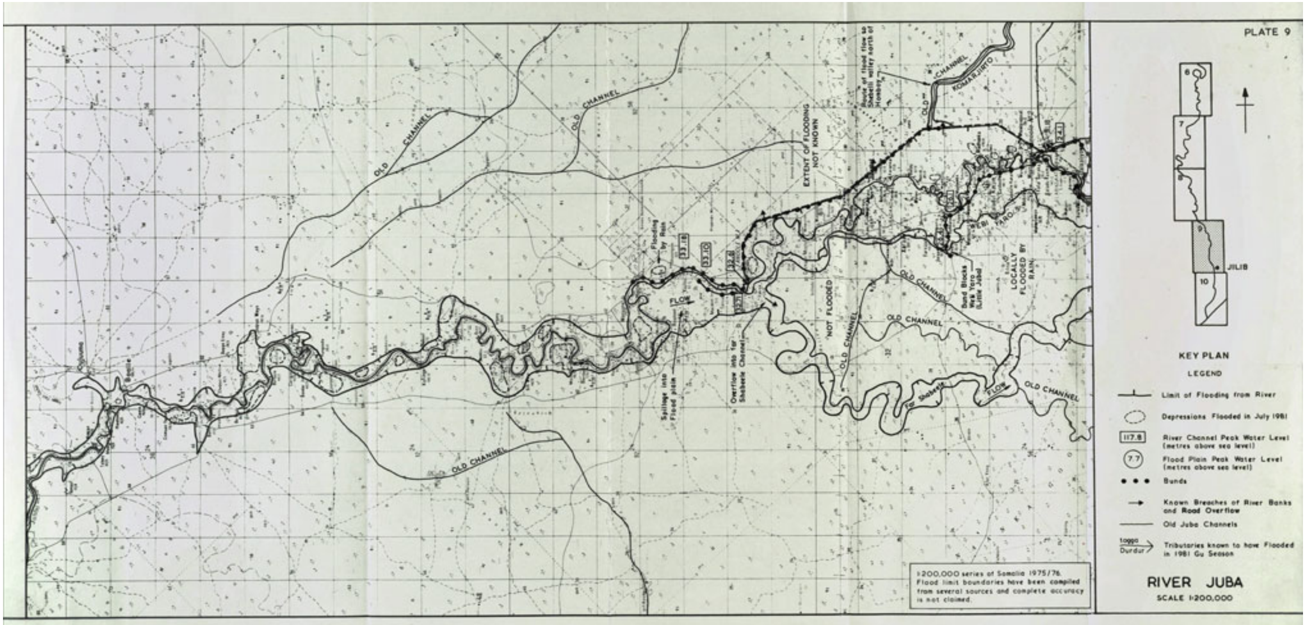

Fig. 14.19 Juba. Flood Damage Study Sheet 9. Juba from Dujuma to Jelib (MMP 1981). Report held by WOSSAC

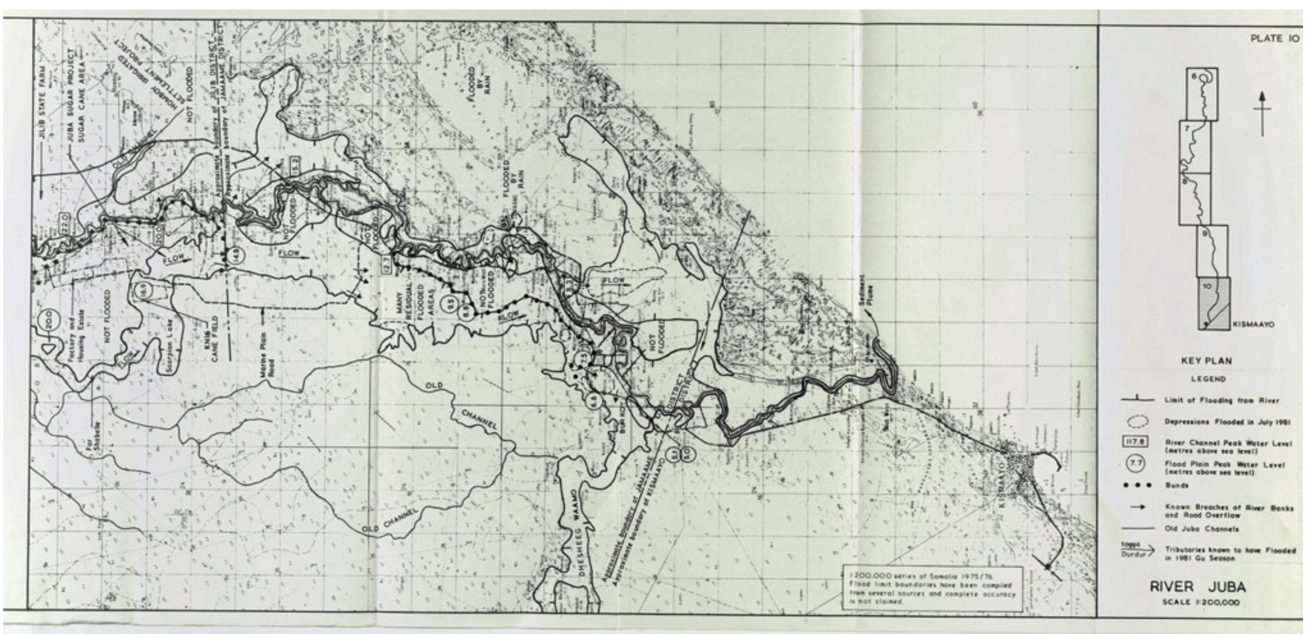

Fig. 14.20 Juba. Flood Damage Study Sheet 10. Juba from Juba Sugar to Indian Ocean (MMP 1981). Report held by WOSSAC

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Fig. 14.21 **a** The Far Shabelle, an old Juba River channel is shown here. View looking upstream (north). The flood was moving towards Scorpion Lake to south (behind the camera). *Photo* RN Munro ©, 29 June 1981. **b** Far Shabelle, 17 January 2016. Same view approximately as Fig. 14.21a. Flow is from bottom to top left into Scorpion Lake. View to south. Marine Plain bushland is more degraded; meanders are perennial wetland swamps. Google Earth ©

management on the heavy Vertisols failed to increase yields, and that given the region is a traditional refuge for livestock in dry season and especially drought periods (Fig. 14.29), pastoral activities could be integrated with rainfed farming.

14.6.3 Conclusions

Large parts of central Somalia fall within the rainfed farming belt, and rainfed cropping is vital to livelihoods. At Farjano and similar areas, where fieldwork is not possible at present, it must be hoped that conditions will change for the better so that modern techniques for improving rainfed farming can be introduced, such as improved seeds, opportunistic planting, weed control, integrated pest management including desert locust control and utilisation of residual soil moisture.

Recent surveys that examined the Farjano area have been made by FAO-SWALIM (Vargas et al. 2007). Some additional future work can be suggested for improving rainfed agriculture:

- The land cover/land use map made for this study can be examined on the ground to see if the vegetation has changed much over the intervening period, as this might show ecological modification as a result of climate change.
- A study by Barkhadle et al. (1994) in Marka and Qoryooley Districts upstream of Farjano found that increased population pressure, overgrazing and fuelwood collection had led to a general degradation of the vegetation, and this has upset an equilibrium in traditional land use where the vegetation was determining land use: in 1994, this

b

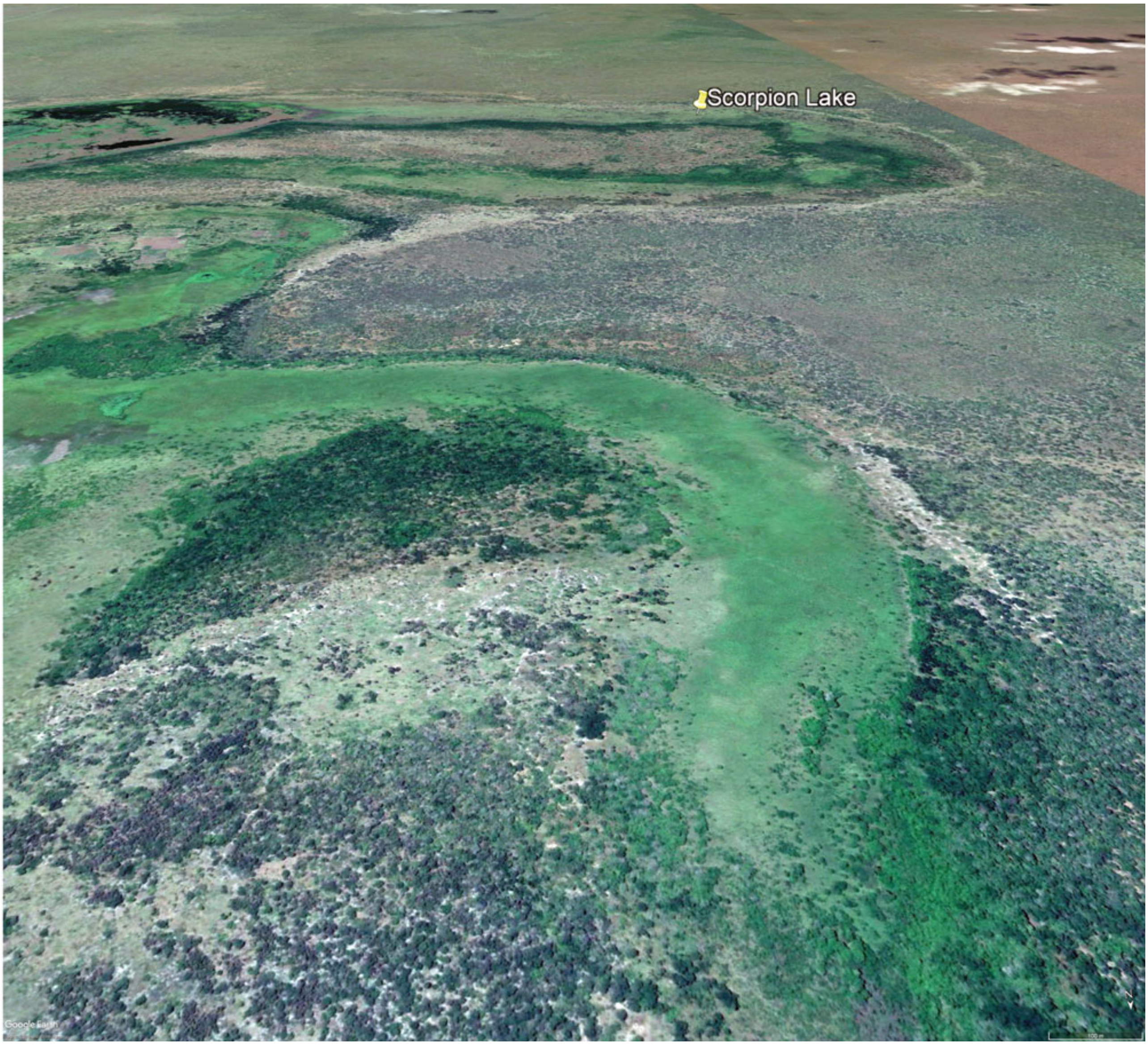

Fig. 14.21 (continued)

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Fig. 14.22 **a** Oblique photo of the Far Shabelle channel flood in Juba Sugar Project that was partly flooded. *Photo* RN Munro ©, 29 June 1981. **b** Scorpion Lake. More elevated oblique view than Fig. 14.28. Image from Google Earth © 17 January 2016 shows the degraded state of this area, hardly recognisable from the 1981 photo. The entire Far Shabelle channel and Scorpion Lake are swamps. Sugar fields are returning to bush, and considerable rehabilitation effort would be required

was reversed, and overgrazing is determining type of vegetation. The present situation is unknown.

- Use of the FAO model *Aquacrop* could help substantially to predict crop failure or success when rains are patchy.
- The Farjano soil sites, and those of other baseline surveys, can be georeferenced from the maps and relocated with reasonable accuracy: a soil sampling programme could examine, for example, if there are significant variations to soil organic carbon (SOC) in the rainfed agricultural lands.
- The Middle Shabelle Flood Control Study (MacDonald 1996) should be updated.
- This study has not examined the status of the rangelands east of the Shabelle, but regarding the tsetse control project of the late 1980s, Matthiessen and Douthwaite (1985) noted that the NTTCP was an exception in that it made extensive land use planning and environmental assessments first, but the overall results were not yet clear—the paper was published as the endosulfan spraying programme was starting. A global ban on the manufacture and use of endosulfan took effect during 2012, and the current status of the environment along the Shabelle due to the use of the endosulfan is not known, and an update on this and the tsetse situation is wanting.

14.7 Case Study: Assessment of Forest Ecology Along Middle Juba

14.7.1 Survey of the Forests in 1986

Under the patronage of Professor Lewis and Sir James Lighthill of University College London, the Somalia Research Project (SRP) made studies on the Juba during 1986. Led by Ecologist Jane Madgwick, the expedition spent several months studying the ecological status of the remaining areas of riverine forests along the Juba, between Bu’aale and Maname. The study of the Juba forests between Saacow and Fanoole had been proposed as a National Park and had the overall aim to assess the potential for establishing a reserve in terms of both human use and wildlife

b

Fig. 14.22 (continued)

conservation and to preserve the riverine forests (Madgwick 1984). The Barako and Shoonto area had been declared forest reserves in 1984 following assessments that showed a loss of over 50% between 1960 and 1984 (GTZ 1984; Madgwick et al. 1986). The results of the expedition were reported by Madgwick et al. (1988) and Madgwick (1989, 1990, 2000). The SRP expedition also studied the zoology of the forests (Varty 1988, 1990; Varty and Hill 1988). Other studies were made by Douthwaite (1987) who called them gallery forest: they are probably better termed riverine forest (see Wickens 1976, for a definition of gallery forest).

In terms of flora, the SRP found some 50 species of trees and shrubs in the levee forest, some up to 30 m high. There was a dense understory, and natural regeneration was common. Away from the river edge was a more open woodland, with large crowned *Acacia.* The transition between forest, woodland and bush was relatively sharp. The forest fauna included some 20 species of birds, specialists of riverine forest, who would be likely lost to Somalia if the last forest blocks would be cleared. Many trees found there rely on bats for pollination. The SRP also observed some 32 species of large and small mammals, some of the biggest concentrations in Somalia. Some large mammals visited during the long dry season moving in from the surrounding bushlands, but others, such as the red forest duiker, blue monkey and greater bushbaby, were restricted to these forests. Forest loss was quantified using aerial photographs by Deshmukh (1987) and Madgwick et al. (1988) for three different dates. Between 1960 and 1987, forest was reduced in area from 93.5 to 9.0 km^2. By 1986, at time of the SRP, the residue was fragmented and sizeable areas of riverine forest only existed in the Middle Juba between Fanoole and Bu'aale, but here over 8.5 km^2 of forest was cleared between 1983/4 and 1987. The SRP recommendations are shown in Fig. 14.30. In the two remaining blocks of forest, the main issue was to prevent cultivation encroaching further into the forests, with provision of forest guards and notice boards. However, the team of Madgwick et al. (1988) concluded that the two largest remaining forest blocks (Barako Madow and Shoonto) of the middle Juba remained relatively intact at that time, whilst all other stretches had become fragmented and degraded. These two areas were gazetted by the National Range Agency as forest reserves and had survived since, being valued and protected by local communities. Madgwick et al. (1988) recorded their importance for gathering wild honey, the source of medicines and fibre as well as affording

Fig. 14.23 **a** Mogambo Irrigation Project (MIP) area. Mosaic of 1963 AP—prior to development. *Note* old channels of Juba up to 11 km west of current channel. *Source* RN Munro AP archives. Print donated to NCAP, UK). **b** Mogambo. 2016 scene from Google Earth ©. The extent of irrigated lands is similar, though the MIP scheme is essentially not operating, main canal abandoned and all reverting to bush

Fig. 14.24 Enlargement of the MIP scheme in January 2016 showing inactive state. North at top. Google Earth ©

villages some protection from floods. The status of the Somali forests was reviewed by Madgwick and colleagues in an IUCN appraisal of coastal forests (Burgess and Clarke 2000). It was stated that little riverine forest remains in Somalia as most has been cleared for farmland and considered that while in the past forest would have existed along both rivers, on the Shabelle only a small and degraded fragment remained at the Balcad Reserve near Mogadishu. The legal status of the forests is that they remain unprotected.

14.7.2 Present Status

The status of the forests and need for their conservation was further noted by IUCN (1991). A more recent assessment of the forests in Somalia was prepared for the 2015 Global Forest Resources Assessment by Somali foresters (FAO 2014), but this report was limited in providing a sound baseline since fieldwork was not possible and remote sensing was not utilised: most of the report is based on estimates made from extrapolating old data. Unfortunately, they did not study the SRP works noted above that could have provided a baseline for comparative assessment. They reported that no national forest inventory has been made since 1980; all government documents were destroyed in the civil war; overall Somali forest and woodland resources represent a small percentage of the land area; recurrent drought is a serious issue; deforestation is prevalent but even so can barely meet local demands for fuel and wood products.

In 1958, aerial photography showed there was much more forest cover in this area. Figure 14.31a is from the 1958 RAF photography that was constructed into 1:60.000 scale negative mosaic by HSL in 1960 for the FAO Land and Water Surveys. The contrast between the bushlands of Marine Plain (dark) and Juba alluvium (light) defines the floodplain with clarity. Dry season AP shows high reflectance of grass and fields on floodplain soils, likely due to overexposure in mosaic making. What is not so clear are the forests shown in the 1986 surveys and the amount of forest cover: one needs to make stereo interpretation of the individual APs held at NCAP to assess canopy and forest structure. Figure 14.31b, from Madgwick (1988), shows the extent of the residual riverine forests in the SRP study area in 1986. Figure 14.31c is a Google Earth image from 2017 of the same reach of the Juba.

Comparing these by zooming in with Google Earth, one can observe that substantial remnants of the riverine forest and woodland mapped in 1986 still appear to remain

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Fig. 14.25 **a** Oblique photo in the lower Juba area. Clear that some parts received no overbank floods. Large depressions between Juba and coastal dunes in far distance remained inundated for many months backing up against the dunes. *Photo* RN Munro ©, 29 June 1981. **b** Lower Juba 14 km SW of Jamaame, the 1981 flooded area remains a back-swamp basin lying between Juba and an old channel. The forest cover is considerably reduced along the Juba, but not disappeared. The tall lines of trees as windbreaks have all been cut down. Irrigation is patchy, and some canals appear to be used as tracks. Altogether a rather degraded picture is apparent. Google Earth © imaged on 17 January 2016

relatively intact in this reach, especially in and around Shoonto Forest Reserve, but parts have been converted to mango plantations and irrigated farmland. The dense, tall evergreen levee forest on the big meander of Barako Madow forest reserve has been partially cleared. There has been encroachment of farmland along the levees close to the Juba, but significant dense forest remains on the lower-lying cover plains that surround the back-swamps and old meander loops —the *desheega* basins that remain flooded throughout the year and are not suitable for agriculture. This is all very encouraging, though of course it is difficult to examine the biodiversity in any detail without a field study. The status of the fauna is completely unknown.

Further south towards Gilib, downstream of the CRP area, and onwards to the Indian Ocean, similar small patches of dense riverine forest remain, often adjacent to groves of huge mango trees along levees.

14.7.3 Conclusions

While parts of the original riverine forest remain, the status of faunal and floral biodiversity in the forest of the Juba is elsewhere seriously degraded by deforestation and encroachment of farmland into arable alluvial lands. The Juba Valley is a river system with an active meander belt that periodically cuts new channels. There are also numerous old channels that are still extant and will remain so for hundreds of years. As seen from studying recent imagery though, it is clear these old channels and associated back-swamp basin areas are perennial wetlands and their fringes support riverine forest. A new study to assess all this on the ground is overdue but difficult to achieve at the present time when there is a poor security situation.

In the past, IUCN (2006) reported that biodiversity conservation had a low priority in Somalia. This is

b

Fig. 14.25 (continued)

changing. In 2014, Somalia contributed an important assessment to the Convention on Biological Diversity (Ministry Fisheries and Marine Resources 2014). This covered Somalia, Somaliland and Puntland, and stated that there had been no effective biodiversity resource management and protection for areas since 1991, when the civil war started. In preparing for the 2020 biodiversity target, the report stated that "the most serious concern is the lack of effective legislation and management of protected areas, and absence of a functioning conservation infrastructure. There are fourteen protected areas, representing 0.8% of total land area, with only one measuring more than 100,000 hectares, namely Lag Badana National Park. Eleven wildlife areas had been declared since the 1970s, but only two were thought to be functional. In practice, there has been no formal protection offered to any of these sites since the early 1990s". The concerns over Somalia's biodiversity and environmental status continue to be raised: SWALIM has been making numerous surveys; UNEP made an environmental desk study that led from the impact of the 2004 tsunami to a countrywide survey with a useful bibliography (UNEP 2005) and produced a useful map showing the traditional ecological classification (Barkhadle 1993); biodiversity was further discussed by Ulla and Gadain (2016); the Ministry of Planning, Investment and Economic Development prepared a drought impact and needs assessment (MoPIED, 2018), and this complements the *Somalia National Action Programme for the United Nations Convention to Combat Desertification* (UNDP 2016) and the most recent assessment by the World Bank and FAO (2018) "Rebuilding Resilient and Sustainable Agriculture—Somalia Economic Memorandum". There is thus no shortage of willing and also plans and programmes for Somalia to rebuild its landscape.

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Fig. 14.26 **a** Part of Ionte Irrigation District flooded in 1981. This lies 20 km SW of Mogambo scheme. Main road to Ionte and Kismayu at base. *Photo* RN Munro ©, 29 June 1981. **b** Same area shown on Google Earth © dated 7 February 2011. Dry season image. Irrigated lands that lie near the Juba have mostly replaced riverine forest. Other parts are poorly drained, a perennial wetland swamp; other terrains are not irrigated and appear to be reverting to bush

14.8 Case Study: Observations on the Coastal Dunes and Northern Escarpment

14.8.1 The Old Red Sandridge

The Old Red Sandridge, also termed the "Big Somali Dune" (Pignatti et al. 1993) and the "Merka red dune" (Carbone and Accordi 2000; Carbone et al. 1981), is up to 100 m high in places, up to 15 km width (Clark 1972), and is partly a relict feature stabilised and rubefied earlier in the Quaternary during moister phases but with active dune formation from reworked red sands and with dunes moving inland from sands blown onshore at beaches. Sands move north-eastwards along the Somali coast and are derived from offshore sediments of the Juba/Shabelle and Tana Rivers.

Angelucci et al. (1983, 1994, 1995), who examined the area between Mogadishu and Merka, considered the red sands were derived from basement complex metamorphic rocks in the Bur area of Somalia and that the red sands were mostly fluvial deposits. Their stratigraphy showed, from base: basal brecciated limestone bedrock, red sand with caliche (2 m), aeolian red sand with cross-lamination (10 m), red quart-rich sands with bands of white sand (25 m) and active dunes (4 m). The red sands and beach rock calcarenites were regarded as partly heteropic, derived from different rock types. These authors reported that the sands could be used for

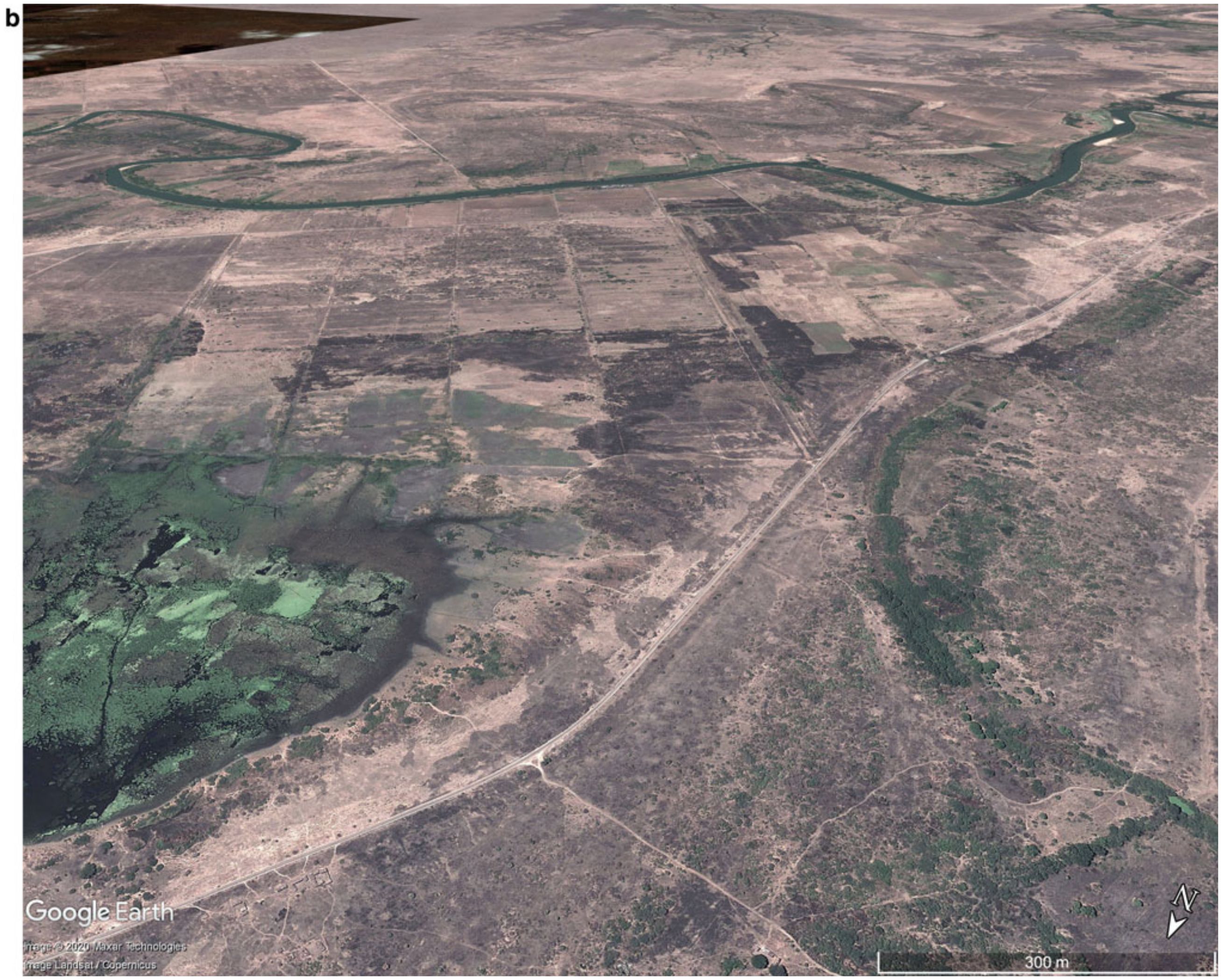

Fig. 14.26 (continued)

a glass industry, and in the laterised red sands, extraction of Co, Ni, Sc, R, V, Cr, Ti, zircon, ilmenite, kyanite and rutile was possible, though the resource was not quantified nor was any environmental impact assessment provided on how such an extraction would affect dune stabilisation, biodiversity, pastoral activities, water pollution and rainfall.

Brook et al. (1996) and Brook (2002) have used a date from coral reef to indicate the age of the easternmost dunes in the Mogadishu area where they overlie coral reefs. This was in an 11-m-thick sequence of the Ras Aw Maki calcarenite at a quarry near Mogadishu Airport that comprised bioclastic calarenite, reefal bodies and coralgal facies with beach sand and cross-laminated sands above. A coral-rich unit 4 m above sea level was dated by ^{230}Th/^{234}U at 82 ± 6 ka: this was during Marine Isotope Stage MIS 5a when sea level was approximately 20 m below present, and thus tectonic movement has occurred since then. But dune sediments have been found in boreholes well below present sea level and suggest aeolian activity during at least MIS 6 when sea level was at −140 m (Brook 2002; Carbone et al. 1984; Angelucci et al. 1995). This was likely related to movement on two major faults (and others offshore) that lie subparallel to the coast and mark the location of the Somali Coastal Basin (Ali Kasim et al. (2002). The Brava sands may be partly contemporaneous with the beach calcarenite aeolian sands but most accumulated later than 80 ka and were brought onshore from exposed offshore sands at times of low sea level. Brook (2002) showed that post-depositional changes included weathering of feldspars and hornblende leading to formation of kaolinite (with up to 10% clay content) and iron oxides coatings on quartz grains, down to a depth of at least 20 m; later on, erosion of the fixed dunes

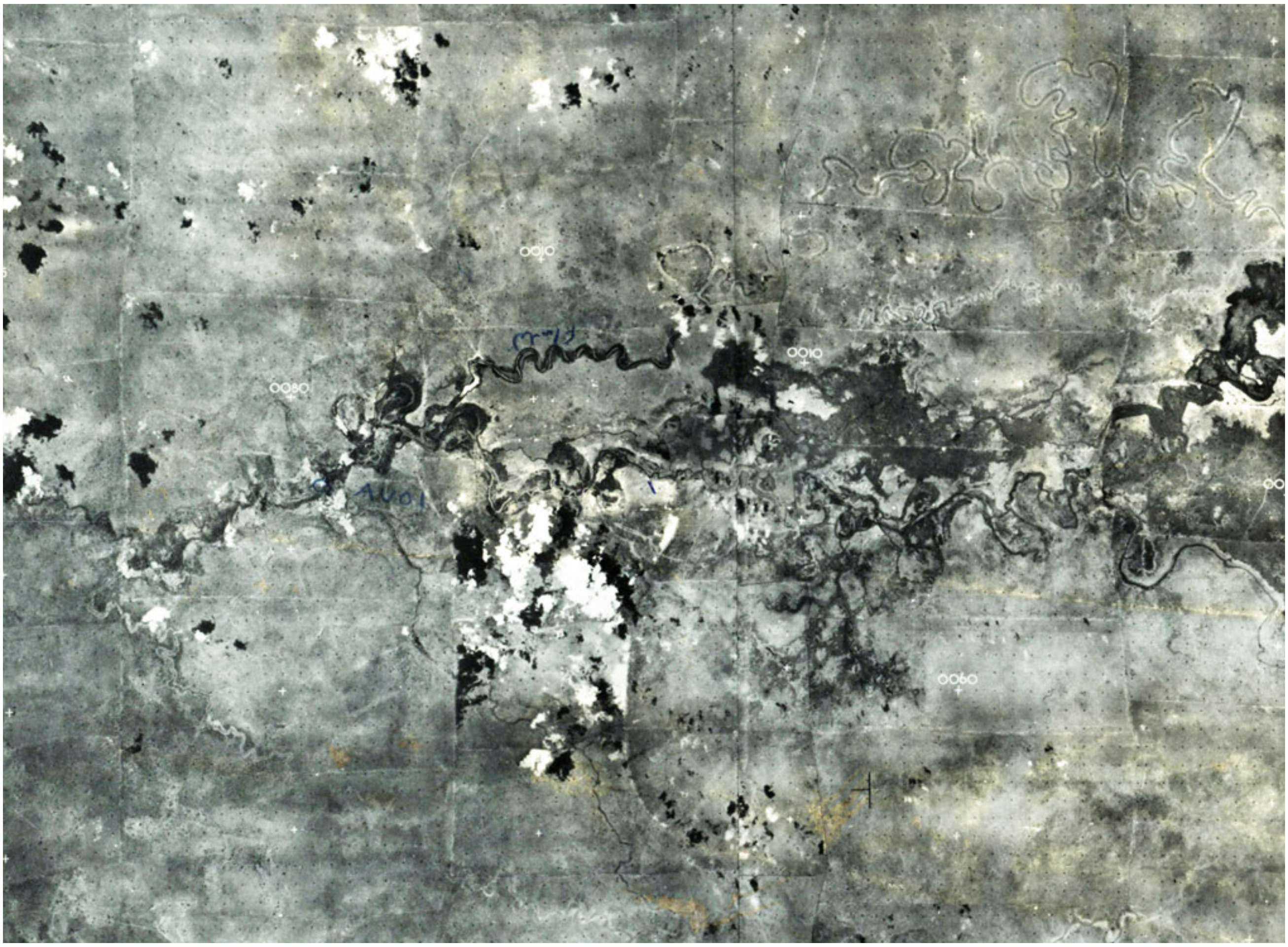

Fig. 14.27 Avai-Farjano-Sablaale Area/ HSL Mosaic at 1:200,000 made from 1958 RAF AP. Ref Block 1, Sheet 9. *Source* RNM AP archives. Original negative now with NCAP, Edinburgh

produced deep gullies on upper slopes, yardangs formed on the lower slopes from residual parts of rills, and gullies cut into the stabilised sands.

Our study of the imagery and aerial photography shows that parabolic dunes spread inland and built up the ridge, probably repeatedly. Given the extent of the sand ridge into Kenya, the mouth of the Tana River and longshore drift towards the NE, we think provenance could well be from a larger catchment area than just the Bur Region. Sands appear to have originated from the Tana, Juba and Shabelle Rivers as they debauched sediments along the coast. In addition, if the red sands were fluvially deposited, it is not clear how this could build up into a sand ridge formation in places 100 m above sea level. The ridge is underlain by beach rock and coral formations well exposed at Brava and Merka that probably constitute the seawards edge of an ancient lagoon. In fact, Artini (1915), 1926) concluded that the mineralogical composition of the dune sands, from Kenya to Mogadishu, corresponded to Juba River sands. Mussi (1975) developed this further to suggest that the dunes built up during periods of low sea levels during glacial epochs, similar to what RNM found on the Yemen Tihama (Munro and Wilkinson 2007).

Stabilisation of dune sands will take place whenever there is rain, but permanent fixing and development of a vegetation cover require a wet season that permits vegetation to cover the landscape and a soil to form. Airborne dust will assist in this process of soil formation. While annual crops (eg millet) can grow on dunes, the stabilisation is lost once soil moisture is utilised and the stover is removed.

At Brava, the chemical changes to the sands as described above will have necessarily been later during repeated moist intervals in the Pleistocene and early Holocene. Williams (2014a, b) discussed the ^{14}C and U-series ages findings of Brook et al. (1997) to show that wet phases in the Horn of Africa occurred at 260–250, 176–160, 116–113, 87–75, 13, 10, 7.5 and 1.5 ka. Soil formation and rubefaction of soils would have transformed active dunes into stable fixed dunes

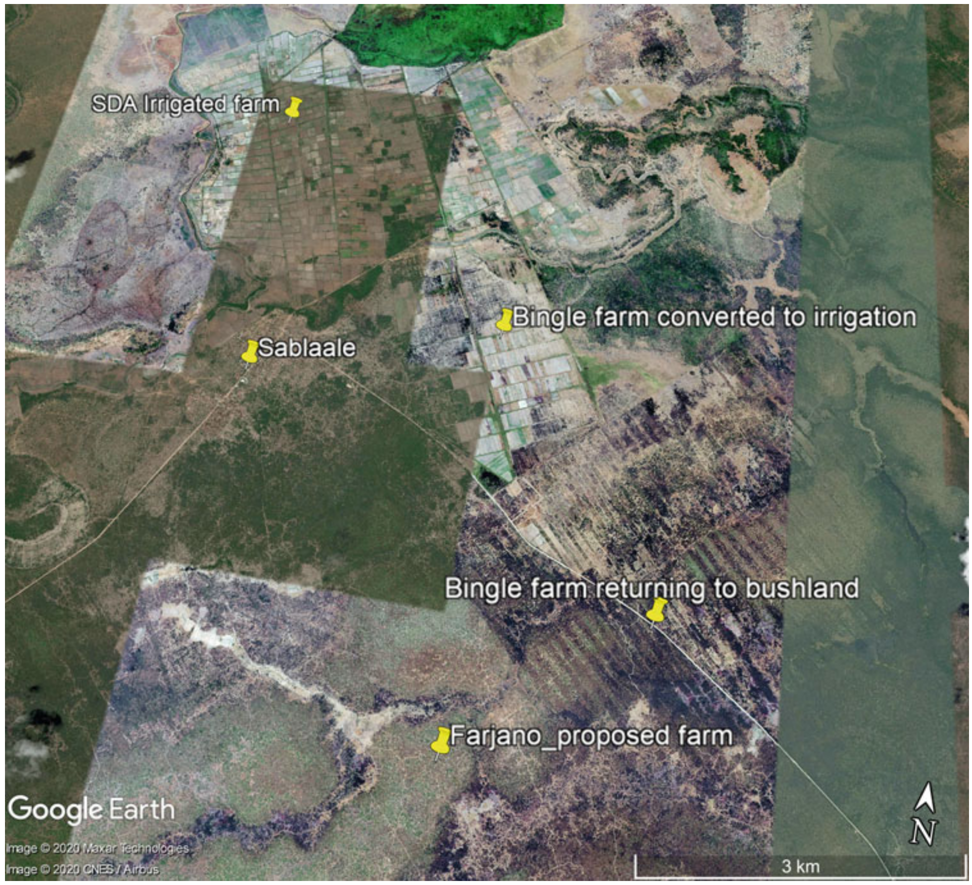

Fig. 14.28 Enlargement of the Farjano area. Google Earth ©. Imagery dates 29 January 2012 and 7 December 2014. The Farjano rainfed farm was never initiated, and 1985 trace lines have disappeared as land reverts to bush. The Bingle Pty Sablaale rainfed farm is partly converted to irrigation and rest reverting to bush

during such wet phases, much like the stabilisation of vast areas of *Qoz* in Darfur and Kordofan, Sudan (Parry and Wickens 1981).

The dunes of Somalia were examined by Lockwood-FAO (1968) who described the soils formed on the stabilised sands. Mainguet (1984) made a useful study of the sands for UNSSO and noted that wind directions and sand movement relate to the seasons: in the Gu (December to March), winds are from east to north-east; in the Der (May to September), from south-west to south. IUCN (1997) examined land degradation and coastal dunes in El Dheer area some 300 km NE of Mogadishu: barchan dunes form on the El Dheer coastal plain (*deh*) as source-bordering dunes from the stream beds (*doh)* and move in zigzag fashion to WSW in Jilal season, and then to NNE in monsoon season.

Examination of Google Earth and older photography (Table 14.1) shows that the landwards edge of the dune belt has characteristic AP features consistent with parabolic dune fronts moving onshore and inland from east to west indicating strong Gu season winds.

Along the Somalia coastline though, sands stream north-eastwards subparallel to the coasts, with dunes emerging from the sea and then entering it again, as at Xaafuun far to the north (see below). Longshore drift brings sands along the Somali coast towards the tip of the Horn, and at intervals—where the geography is appropriate—onshore winds bring these sands onto the beaches where they are then blown inland. It is likely the dunes and drifting sands blew much further inland in the past as faint ghostly traces of parabolic forms are seen in places, such as SW of Galkayo. These may indicate wind directions that no longer operate. There are modern active and ancient stabilised sand dunes that occur along a greater part of the coastline of Somalia from Kismayu to Ras Xaafuun and its lagoon, almost to the tip of the Horn of Africa itself.

The coastal dunes are stabilised in southern Somalia from Kismayu northwards and for several hundred km beyond Mogadishu and have a surface loamy to sandy surface soil layer and buried paleosols. The dune ridges are up to 110 m high and have a complex history that remains to be deciphered. Modern blowout areas are common, and the sands have pale tones and appear to be moving into the farmlands of the Shabelle. Closer inspection shows that they are relatively stable, the fringes have been protected and protective vegetation has recovered, and the active parts have retained a similar form for over 50 years. In addition, much work has been made to stabilise the dune margins where they impact on irrigable lands and infrastructure.

Fig. 14.29 Just a Dry Season Condition or Example of Drought? Munro in the dry Shabelle, Farjano area, 1985. *Photo* RN Munro ©, 1985

The climax vegetation of *Acacia tortilis* and *Acacia busia* (Pignatii and Warfa 1983; Pignatti et al. 1993) is subject to clearance nearer the settlements. Both local remobilisation of sands and onshore drift of sands appear to be taking place. The lack of stabilisation of mobile sands by vegetation has resulted in numerous blowouts that extend inland over the surface of the sand ridge.

Mainguet's (1980) study had recommended that fragile areas should be closed to animals and afforestation made on the sand ridges where degradation has resulted in reactivation of dunes that threaten the roads and irrigated lands inland. This was a common good practice and timely messages in extension and conservation: they were heeded. At Brava, gully erosion into the old sand ridge was halted by planting a graminaceous cover with trees and *Opuntia sp*. on its upper margins to halt erosive run-off from the crest of the ridge. Within the gullies, check dams were planned to permit accumulation of sediment, but it is not known if these were constructed.

Figure 14.32 a shows a large part of the coastline and interior Shabelle plains of southern Somalia. The mosaic was made from 1958 RAF photography by Hunting Surveys. Brava lies at the promontory at the right-hand side of the image. The ancient dunes, whose inland limit is marked by the irregular difference from dark to light tones, are stabilised by iron-stained soils and $CaCO_3$ concretions throughout. The ancient dunes, deeply gullied in places as at Brava, generally show dark tones on the photography from the shrubby vegetation cover. Figure 14.32 b is a Google Earth image (2011–2017) of the same area that indicates only small changes to the large coastal blowouts over 50 years.

At the same time, large gullies have cut down into the ridge. The date of incision of these gullies is not known, but, at Brava, they are older than the 1958 RAF photography. Elsewhere along the coastal sand ridge, there are numerous examples of old gullies now completely re-vegetated, for example 40–48 km SW of Brava, and some 10 km SW of Merca. Closer to Merca and extending for some 40 km to the NE, there are many rills and gullies cut into the paleosol surface of an old sand massif. Some 5 km SW of Merca, from a well-vegetated coastal zone 1 km wide, the old sand ridge rises sharply up to 50–100 m asl and is characterised by many rills and gullies. The convex top of the massif

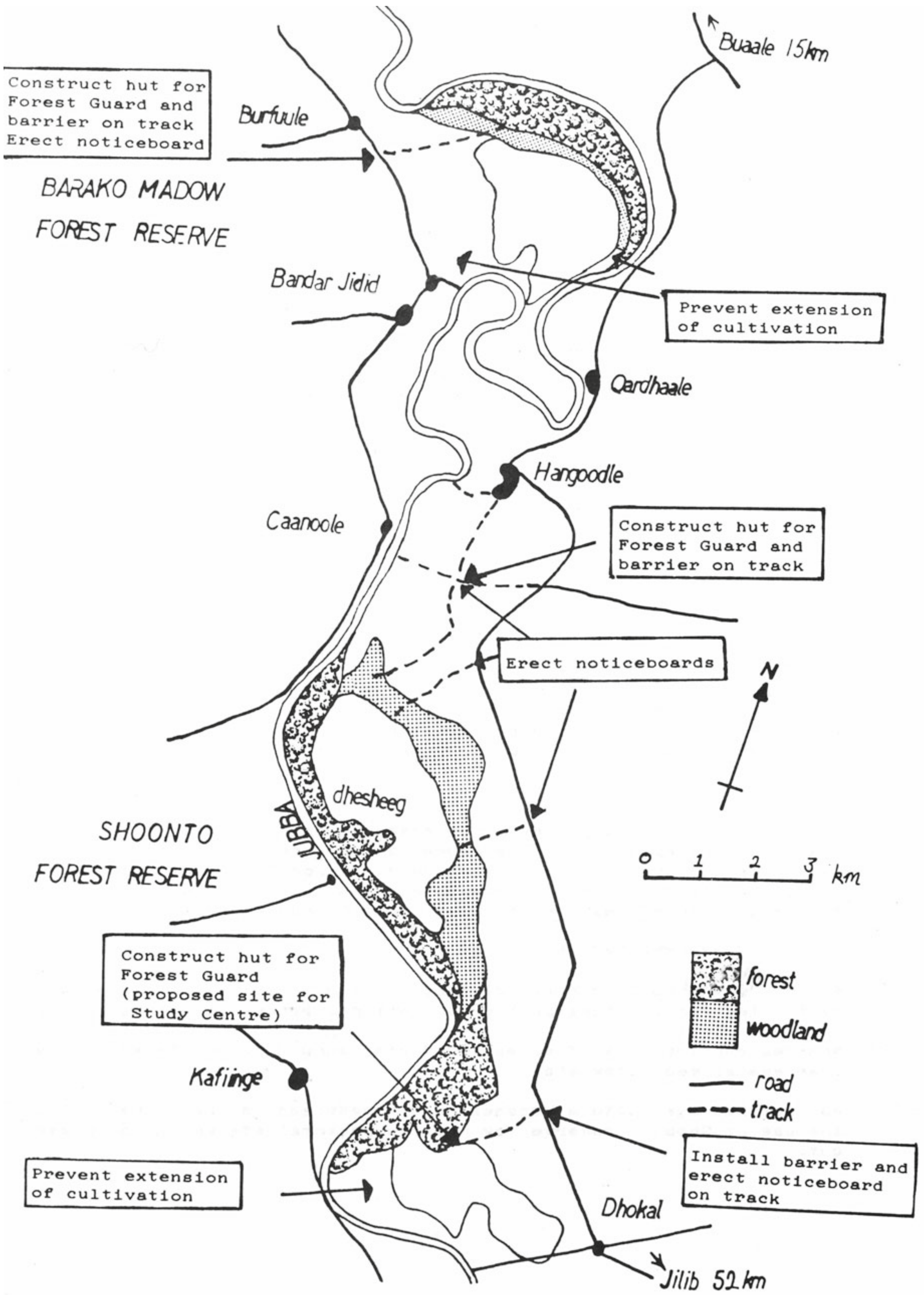

Fig. 14.30 Recommendations of the Somali Research project (Madgwick et al. 1987)

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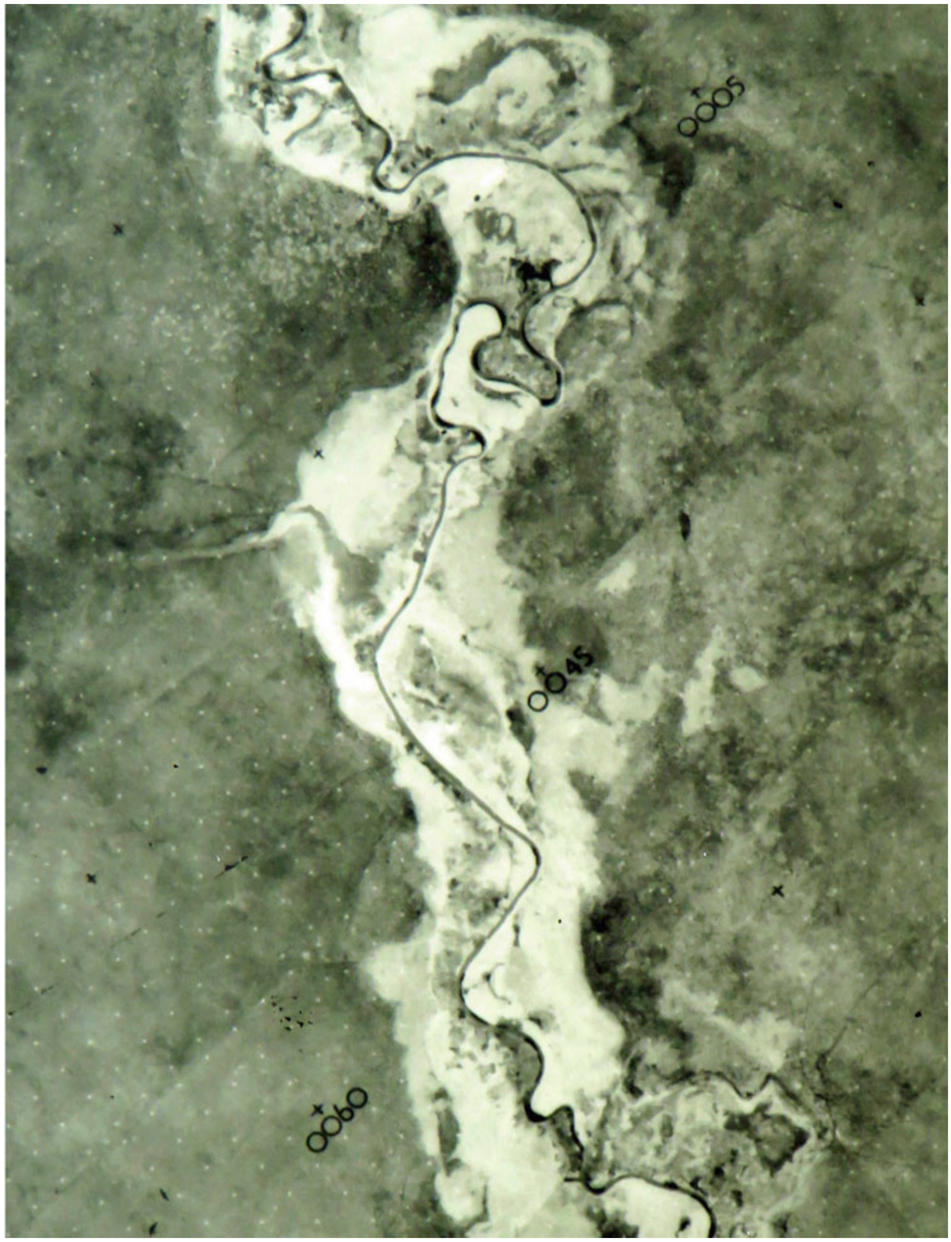

Fig. 14.31 **a** Juba forests between Buale and south of Maname. 1958 RAF photography. Copied from 1:60.000 scale negative mosaic, made by HSL in 1960, converted to positive using Adobe Photoshop Elements. The photograph of the original print lay down was overexposed making differentiation of alluvium and forest difficult. Sheet 37 of 1:60,000 mosaic series D-5890. North is at top. *Source* RN Munro AP archives. During 2020, the original negative will be donated to NCAP, UK. **b** Forests on the Juba (from Madgwick et al. 1988). Shows the two main forest blocks studied on the SRP. **c** Juba forests between Buale and Maname. Same areas as Photo 30. North is at top. Shows that some forest remains and small changes to river morphology. Google Earth ©. Imagery date: 31 March 2017

extends a further 2 km inland and is gradually buried by active dunes that are transverse ridges formed by SW winds with linear ridges and lobes formed by east and south-east winds. The upper part of this relict dune massif is bare without vegetation cover and run-off from rainfall from rills and gullies that are steadily wasting the entire area.

A close-up view of part of this area is given in Fig. 14.33 a, taken in 1968. The image shows parts of the coastal dune ridge 18 km south-west of Brava. The dunes on this December (1968) AP indicate two wind directions from west and north-east. The winds from the west realign sands that stream to the east, modifying the underlying more massive transverse dunes that have south-west facing slip faces. The Google Earth imagery (Fig. 14.33b) taken in December 2014 shows barchan dunes moving onshore and westwards to fuel the transverse dunes. The barchans pile into the transverse dunes that form most of these active massifs. There appears little change in the 1958 mosaic and 1968 vertical photography. By 2014 though, there is evidence of minor adjustment of the loose sands: the road alignment has been shifted some 400 m to the north and west as sands engulfed the road. The edge of the dunes though is now protected by vegetation. The dunes appear to show a complex pattern of different wind directions with regional winds from west and onshore from east at same time: this can be explained by fact that the dunes reach up to 100 m height in this area, while the Shabelle cover plains inland are at 45 m asl and the onshore winds do not reach far inland. Interior winds in fact

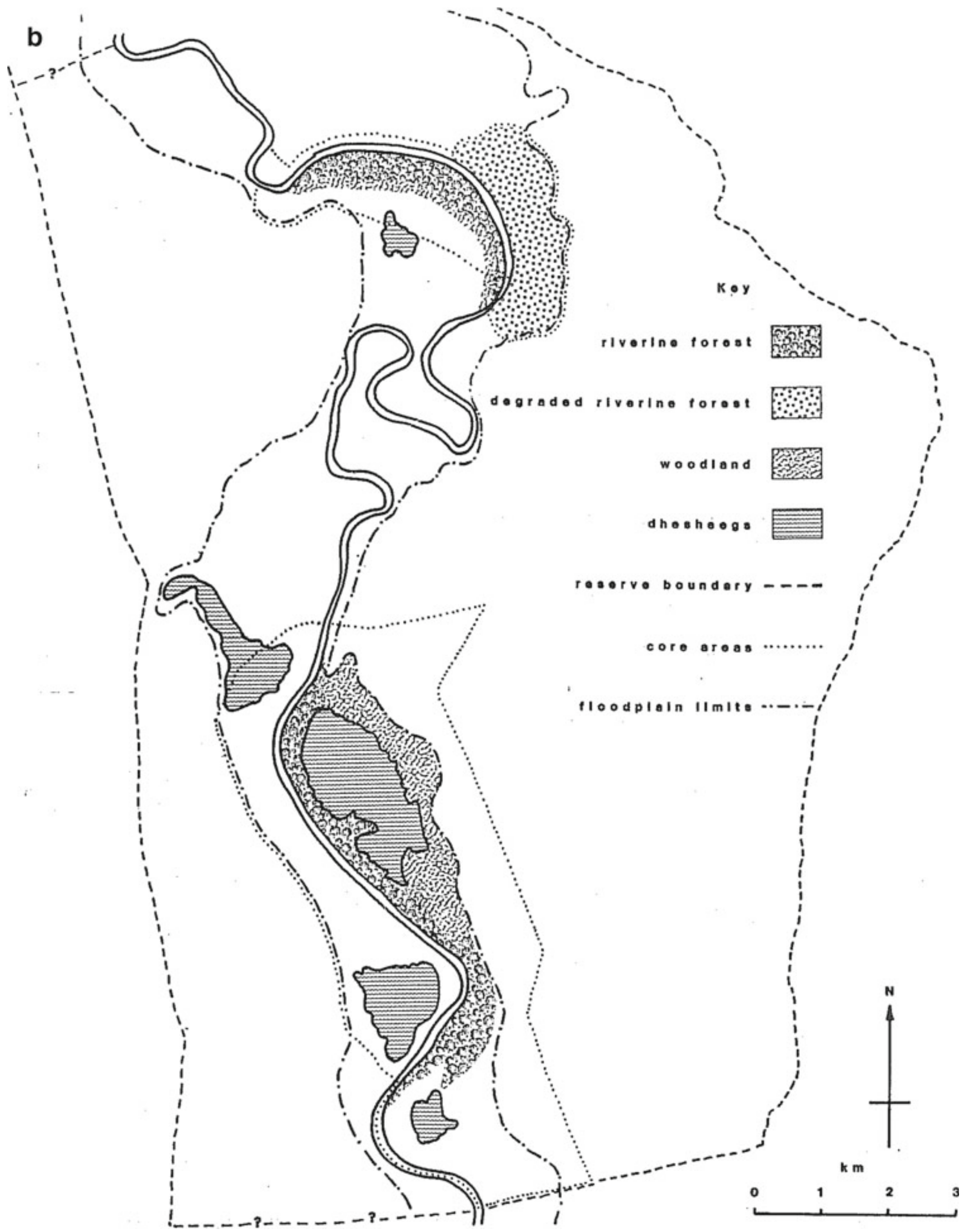

Fig. 14.31 (continued)

c

Fig. 14.31 (continued)

may assist in blocking eastward movement of sands and maintain the dunes where they are.

The situation varies locally: the skilfully made and attractive Italian Military mapping from 1911 provide land cover information and spot heights. The history of Italian mapping in colonial Somalia was documented in excellent monographs by IGM (1939) and Traversi (1964). The Muriole 1:50,000 scale sheet of the El Bacari area, some 31 km ENE of Ione/45 km up the coast from Kismayu, delineates the active dunes (*duna mobile*) and stabilised dunes (*duna stabile*). This identification of active and stable dunes represented an advanced recognition of geomorphic history for the time. Comparing with Google Earth, one can see that *duna mobile* overran *duna stabile* inland and the dune front advanced inland about 1 km (Fig. 14.34a, b). On the 1911 sheet, spot heights made by the topographers show a distinct ridge with elevations reaching 80 m above sea level. Google Earth altimetry here indicates elevations up to 65 m asl: it appears the crest of this dune has been deflated and parts moved inland at some stage between 1911 and 1958: the 1958 photography shows minor changes (not illustrated here due to poor reproduction from the negative), but since then the dunes have moved further inland to the state indicated in the 2011 image.

In a study of the Sar Uanle coast, 20 km south of Kismayu, Vannini et al. (1977) updated the pioneering work by Fantoli (1965) and showed that the winter monsoon winds blow directly off the ocean from the east, but wind speeds in winter were rarely high enough to move sands off the beach.

Yet, the evidence from Google Earth and aerial photography is that strong winds do push sands off the beach. It seems clear that periodically exceptional events, cyclones would seem the likely cause, have occurred to advance the dunes inland. This point was first noted by Mussi (1975).

In Fig. 14.35 a, b, repeat images from 1968 and 2012 show the large gullies (Fig. 14.36) to the immediate north of Brava cut deeply into the ancient (Pleistocene) dune formation massif, but the 2012 Google Earth image indicates that gully headward erosion has been stabilised in terms of further expansion. To the west of Brava and west of the main road (in yellow on Fig. 14.35b), gully stabilisation was initiated on the top of the dunes by the National Range Agency in afforestation schemes in the mid-1980s, notably in Brava area, when RNM assessed the changes. These

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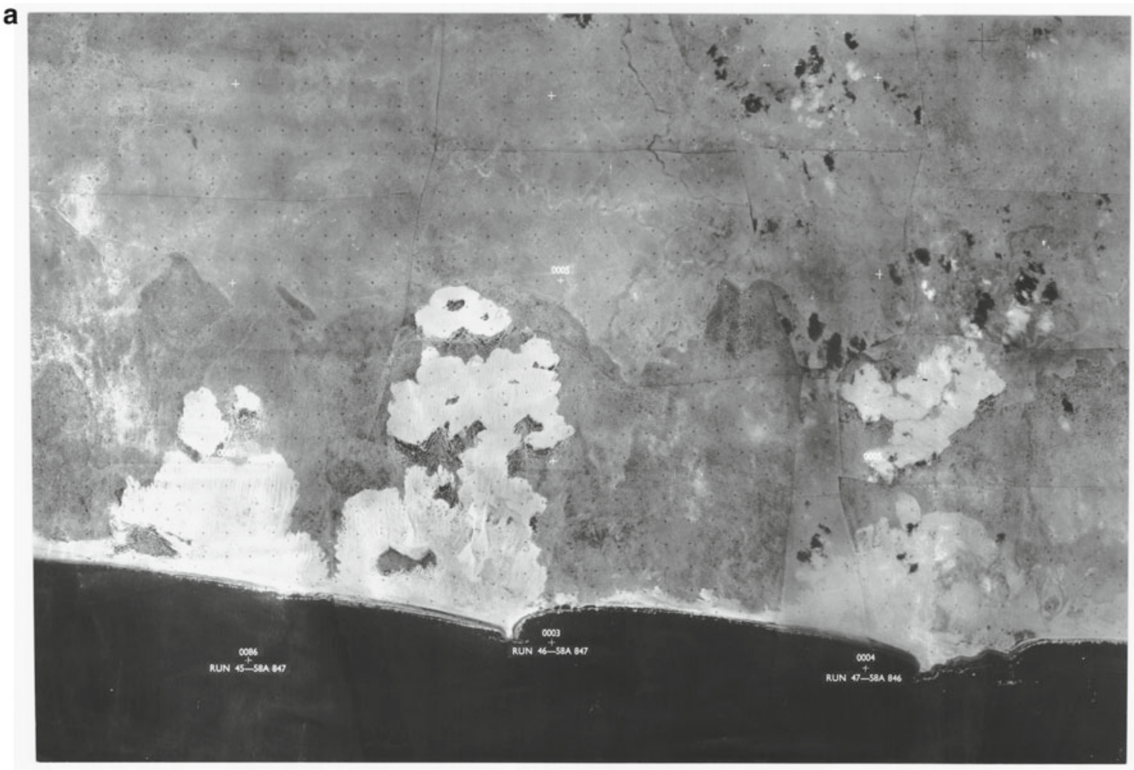

Fig. 14.32 **a** Dunes along southern Somalia. The mosaic (Block 1, Sheet 9 at 1:200,000) was made by HSL in 1970 using 1958 RAF photography. *Source* RN Munro AP archives. During 2020, the original negative will be donated to NCAP, Edinburgh, UK. **b** Google Earth image of same area. Images 2011–2017. Minor modification of the principal parabolic dune blowouts. Interior edge of older parabolic dunes suggests an abrupt phase of stabilisation and rubefaction. Google Earth ©

gullies are clear on the 1958 AP, but are not indicated on an Italian military map of 1910: but even if they existed, then the small scale of 1:200,000 would likely make delineation difficult. It is possible there exist more detailed Italian maps that could be utilised in a future exercise. The formation of the gullies must have been related to intense rainfall cutting rills to expose deep soil of the stabilised dunes. These then were deepened and expanded with headward erosion. On the top of the sand ridge today near Brava, there is considerable encroachment on the bushlands with change to rainfed farmland (top right of Fig. 14.35 b). This encroachment is on the flatter parts of the sand ridge, but nearer to Mogadishu these sand ridges are extensively, and for long, cultivated. At Brava, where the dunes rise up to 110 m above sea level and may catch more moisture, it is a more recent development as the city has expanded from a tiny port in 1985. There are red and white dunes: the red dunes are formed from iron-coated sands eroded out of the ancient dune ridges; the white sands come from the sea: these active sands ride up and over the ancient dune ridge. There will be mixing of both in some places. The stabilisation of the gullies happened after 1985, as RNM visited them at that time (Fig. 14.37), when *Opuntia* (Prickly pear) was seen growing as a stabiliser, reducing erosive rainfall, and likely too as a discouragement to livestock to enter the thickets.

Along another part of the dune belt closer to Mogadishu in 1977, the movement of sands on the landward side of the dune ridge was giving some concern to those planning the proposed development of the Genale-Bulo Marerta irrigation scheme (MMP 1978a. Annex 1: Soils). The Genale-Bulo Marerta Project covered 67,400 ha of lands located on the floodplains of the lower Wabi Shabelle some 100 km south-west of Mogadishu. It was bounded on the south side by the coastal aeolian sand dunes ridges and on north by old channel landforms. The Genale (Janaale) area was first developed in 1926 by Italy, with canals established by 1927 over some 30,000 ha. MPP noted that no other records from this Italian period could be found in Mogadishu. A concern in 1978 was that the coastal dunes inland of Merca would move onto the farmlands of the Genale—Bulo Marerta

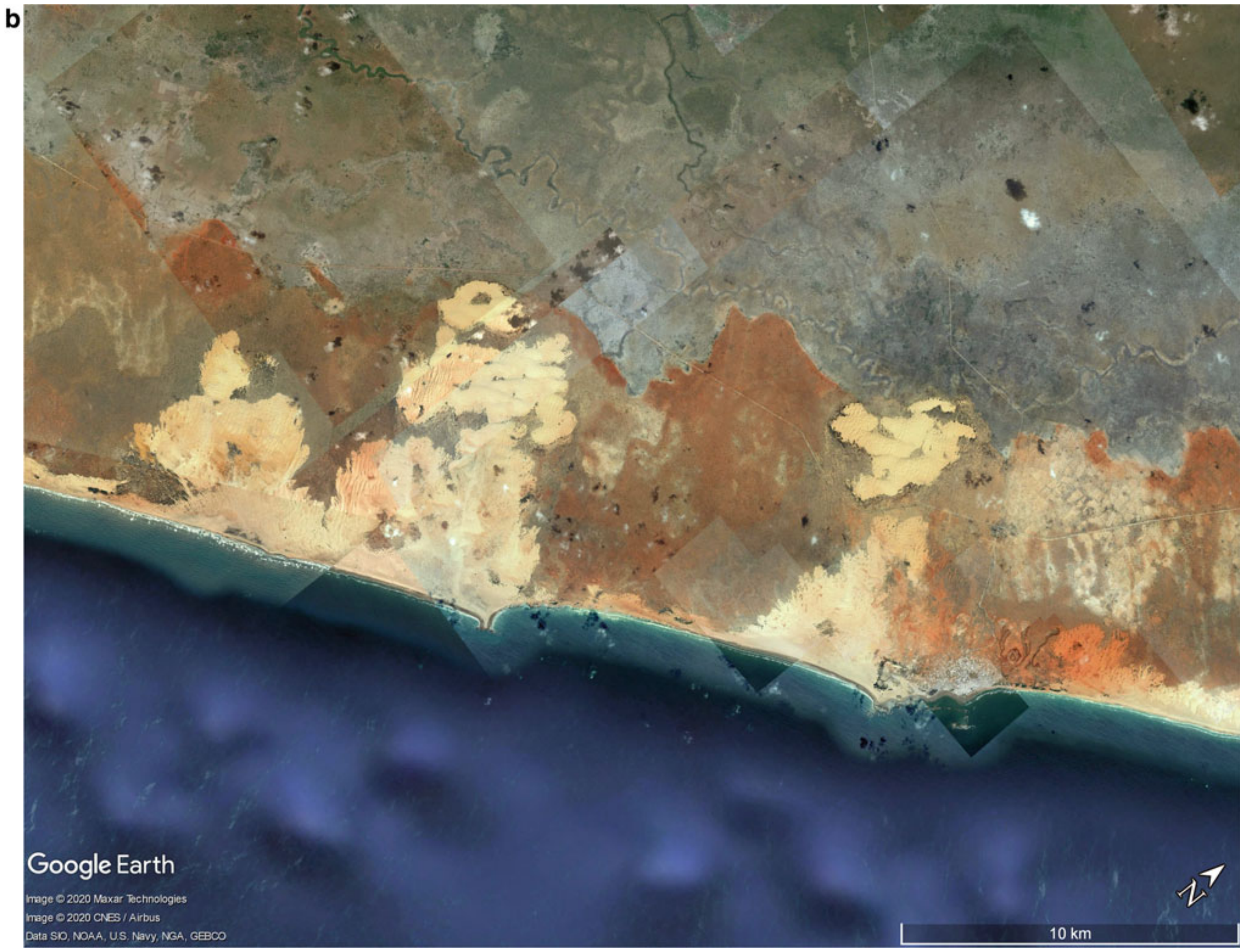

Fig. 14.32 (continued)

scheme and also bury the air strip south-west of Shalambood (Fig. 14.38a). But this did not happen partly due to conservation efforts on the sands and also because the air strip was built parallel to the prevailing wind directions and sand movement. The main drift of sand is to the south-west and the edge of the dunes have been vegetated. The air strip remains free of sand (Fig. 14.38b). Additional comparisons in Shalambood area a little to the north (Fig. 14.39a, b) show that between 1968 when active dunes were threatening to move across the road and 2020, a large effort was made to stabilise the dunes on the landward side. We have not found the details of how this was achieved but was clearly a great success. In general, and in southern Somalia, the juxta-positioning of winds and the presence of shrubby vegetation cover on the sands appear to have limited any major expansion of these dune groups for the last 60 years. These time-lapsed pairs show there has been noticeable afforestation of active dunes, all very promising.

Far to the north-east along the Somali coastline, in a much more arid climate, lies the peninsula of Ras Xaafuun (Hafuun) with a shallow lagoon to the east. Up to the 1940s, this was a very productive area for salt evaporation by the Italians and local communities, but destroyed by Allied forces in 1940. The remains of the pans occur around the lagoon near Hordio in the 1958 mosaic (Fig. 14.40a) and the modern Google Image (Fig. 14.40b). The southern margin of the lagoon is a sand bar that was covered by the 26 December 2004 tsunami: since then, a new town of Xaafuun has been built on the higher ground of Ras Xaafuun, actually quite close to the old Italian settlement of Hafuun that they called Dante. The modern village is secure from any future events, and efforts have been made to assist the communities and hopefully revitalise the salt industry.

The mosaic print shown in Fig. 14.41 is a part of Sheet G-13, Block 4, in the D-6294 mosaic series of Northern Somalia. Made from 1958 RAF photography, it lies just

a

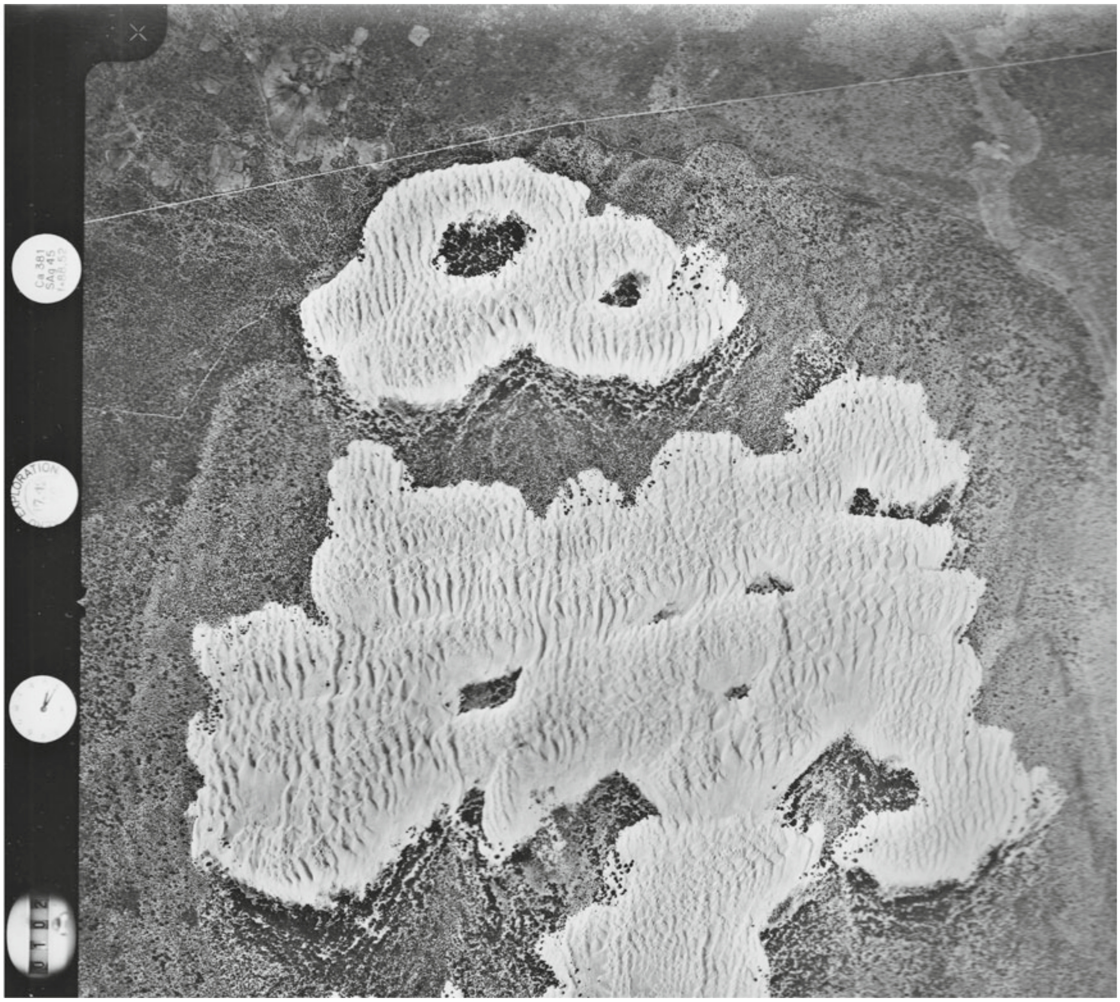

Fig. 14.33 **a** Aerial photograph from 17 December 1968. Enlargement of coastal dunes seen in Photo 32 and 33. *Source* RNMunro AP archives donated to NCAP. **b** Google Earth © image of the same area appears very similar with slight modification after 46 years. December 2014. Google Earth ©

north of the Ras Xaafuun (Hafuun) lagoon. The coastline at extreme right is at approximately 10.955323° N, 51.117796° E. Immediately north of the lagoon ephemeral streams enter the coastal plain. These drain the interior plains underlain by Eocene to Miocene limestone, evaporites and sandstones. The latter contribute some sands that will deflate, as source-bordering dunes, but it is clear that most of the barchan dunes are derived from sands emerging from the sea and drift northwards. Enlargements of the 1958 mosaic (Fig. 14.42a) and recent Google Earth imagery (Fig. 14.42b) show this process as sands emerge from the sea and drift over the sand bar. Along this part of the coast, there is a north-easterly movement of barchan dunes along the coastal plain that then re-enter the sea again—at the right-hand edge of this mosaic. Comparing the mosaic with the situation now, the accuracy of this uncontrolled print lay down mosaic is good; the direction and numbers of barchan dunes appear similar, and in monochrome rather clearer than in the colour imagery of Google Earth; and the density of vegetation in wadi lines and on sandy plains appears much the same.

14.8.2 Dust Hot Spots

A recent global dust assessment (UNEP, WMO, UNCCD 2016) identified two Somali dust hot spots, regarded as of likely anthropogenic origin: the Nogal Valley (that they also call the Nogal Lake though there is no permanent water feature there) and the Hobyo coastline between Mogadishu and Eil (Eyl). It was not stated if any fieldwork was made to support these claims.

For the coastal zone, the Hobyo comprises grasslands and shrublands and is a desert and xeric scrubland ecoregion: an anthropogenic origin seems doubtful as it is a very dry,

b

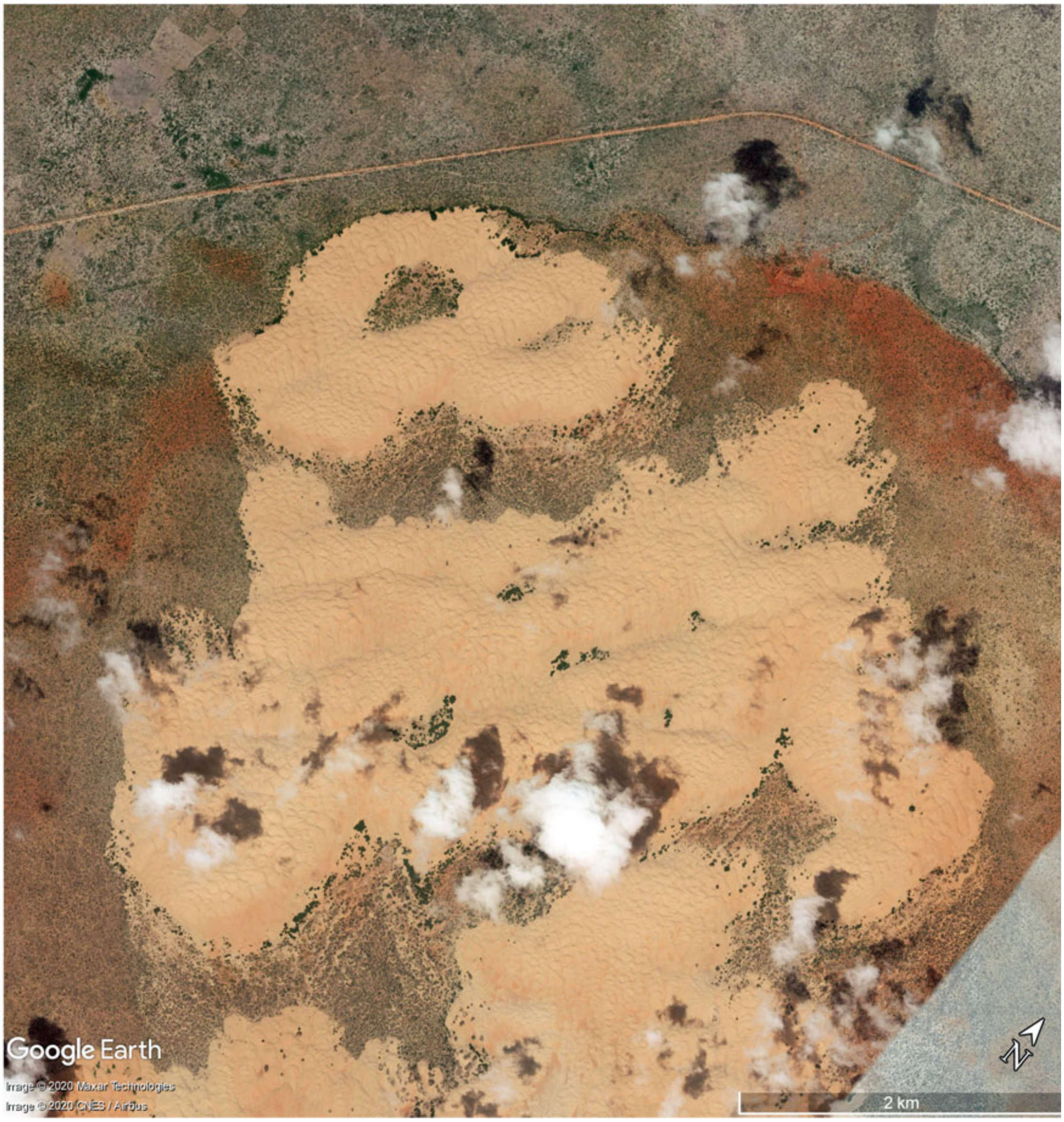

Fig. 14.33 (continued)

mostly sparsely populated and narrow hot coastal desert region. Google Earth imagery shows that sands and finer materials are drifting onshore, in places along a narrow strip backed by steep terrain that precludes movement of sand inland. Elsewhere, sand sheets drift northwards from here up to 60 km inland before entering the sea again close to the most easterly part of the Nogal (Tug Der) Valley.

Inland, the Nogal Valley broadens out. It lies in a tectonic half-graben up to 200 km long (Ali and Lee 2019), cut into Eocene and Pliocene sediments; elevations rise to ca 500 m asl. It is a very dry pastoral area, devoid of vegetation arcs, but with scattered bushes set amidst very pale bedrock and Quaternary fills. The Tug Der is incised into the valley floor and closer to the ocean occupies a narrow canyon. An anthropogenic reason for dust generation in the Nogal basin seems not proven.

14.8.3 Northern Escarpment

In the Horn of Africa, the most north-easterly part of the region, the landscape is arid with little scope for irrigation or water harvesting except very locally. We examine the Ferio Range (10˚18’N, 45˚30’E). One repeat scene shows the relatively unchanging nature of a desert landscape: Fig. 14.43a is a USAAF Trimetrogon K-17 right oblique

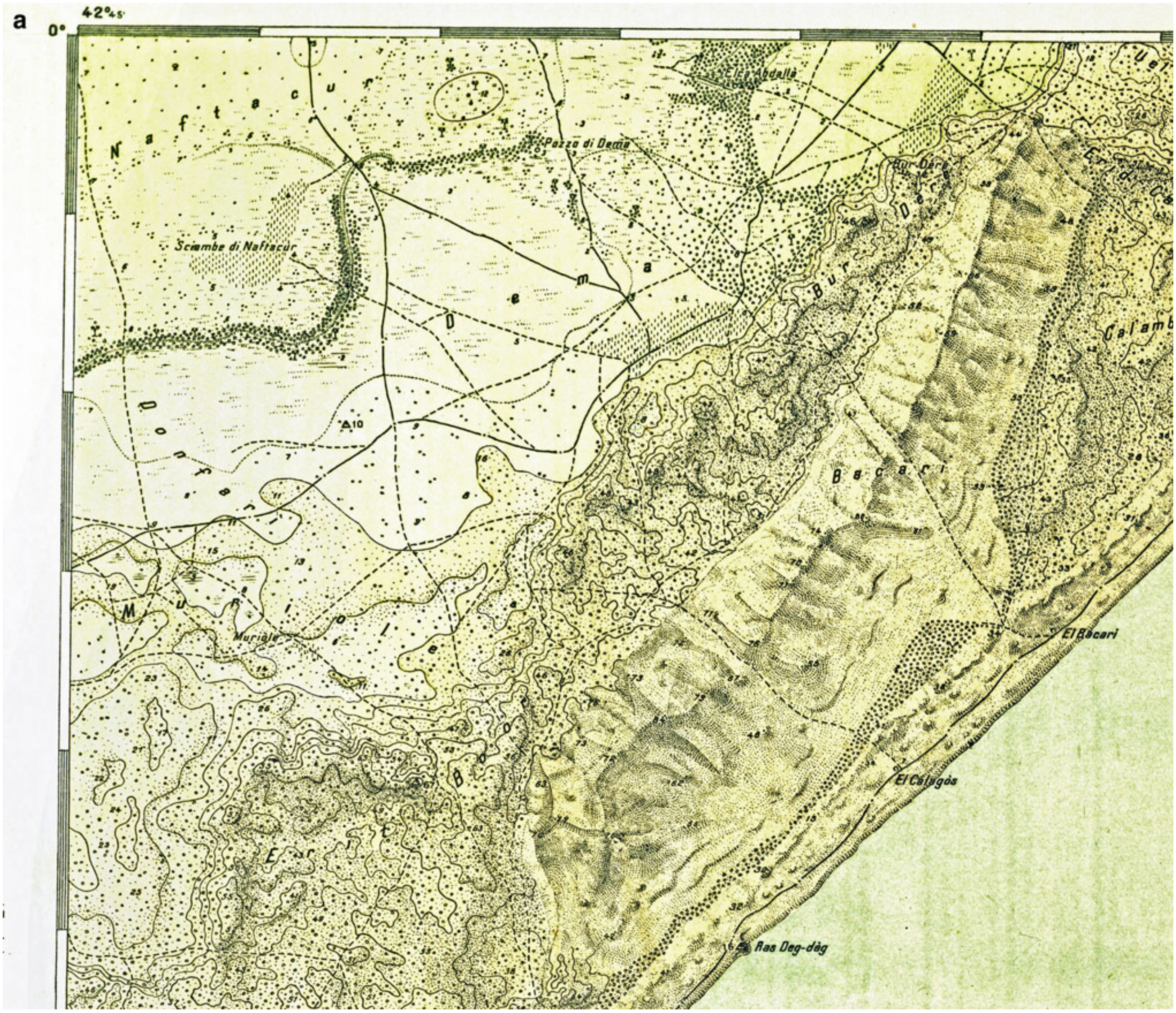

Fig. 14.34 **a** Part of 1:50,000 scale sheet F° 1 (Muriole) from *Carta della Somalian Italiana*, surveyed in 1911 by the Instituto geografico militare. Publication date not given. At right the mobile dune ridge of Bacari with its defined crest, now lost, and vegetated dunes to its west, south and at far right. An old forested course of the Shabelle is at upper left. **b**. The same area is shown in Fig. 14.14. The active dune fronts shown in 1911 later advanced inland as parabolic dunes from west during severe storm events between 1911 and 1958 and also since then, probably as intense and short-lived storms: historical records from cyclones may indicate just when. Traces of older parabolic dune fronts with rubified soils and some cultivation, and more recent paler sands covered by scrub, are clear. Google Earth © image dated 7 February 2011

photo from 1945 of the Ferio Range looking south. Figure 14.43b is from approximately the same viewpoint (27 May 2013) and shows the Ferio Range with the Somaliland plateau in background. These oblique views are made from a point some 40 km east of Berbera. In general, the two images 68 years apart seem initially to be much the same, as might be expected in an arid zone. However, the arboreal vegetation in the streams at lower left appears denser than in 1945, and stream course changes can be observed on the alluvial fan complex at right centre. An additional feature is that red aeolian sands at the base of the Cretaceous Yesomma Sandstone cliffs at lower left move northwards as sand sheets and barchans amidst tussock grassland. The active grass tussock dunes move northwards, from one of the few inland sand source areas on the escarpment, while other dunes move southwards off the sea: these meet in a zone of star dunes up to 50 m high. Off-screen from Fig. 14.43b, these sands merge with a series of southwards-moving onshore dunes from the coast forming chains of east–west aligned "mini" star dune complexes. These areas received torrential storms from Tropical Cyclone Pawan in December 2019 (IFRC 2019).

b


Fig. 14.34 (continued)

Further east, Brook et al. (1990a, 1990b, 1998) examined massive and inactive stalactites and stalagmites in two caves on the Golis Range, and $^{230}Th/^{234}U$ Uranium series dating of speleothems and tufa formations showed these were formed during several phases (at 116,000–113,000; 87,000–75,000; 12,000–4000 yr B.P., though with large uncertainties) during interglacial periods, and that isotope stages 1 and 5 were here represented by increased moisture and a strong south-west monsoonal air flow. Analysis of pollen data, however, suggested that the Golis area did not support rain forest or montane forest vegetation during the time periods of the dated speleothems. They considered that the few occurrences of *Juniperus* pollen probably relate to patches of dry woodland with *Juniperus*: similar forest occurs today on the Golis escarpment edge north of Erigavo (Pichi-Sermolli 1955).

14.8.4 Conclusions

The huge blowout features of the coastal dune ridge along the coastline show minor change since the 1950s. The prevailing wind directions today mean that movement further inland of the dunes onto the cultivated alluvial soils is minimal, despite the menacing appearance of the blowouts. All that could change in a world of global change that could include changes to wind directions and strengths. This has happened in the past when mobile sands covered the margins of the Shabelle alluvial lands. While sand is coming onshore at various locations, such as at Brava, attempts to stabilise active sands have been quite successful: such work needs to be maintained. Natural stabilisation of gully systems is noted between Brava and Kismayu in the higher rainfall zone, but

a

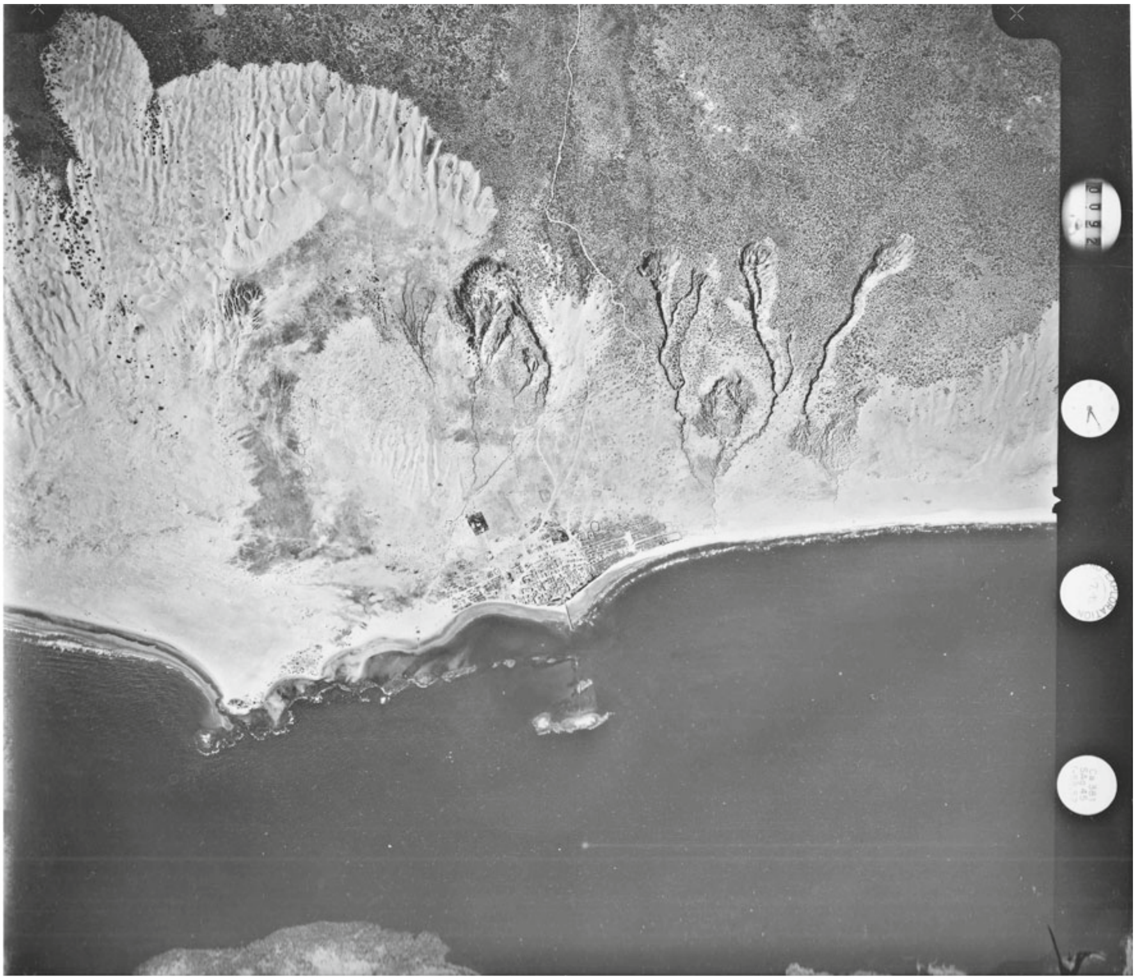

Fig. 14.35 **a** Gullies in the ancient dunes at Brava. December 1968 aerial photography. The gullies appear to have formed, in part, along an old track over the dunes. *Source* RNMunro AP archives donated to NCAP. Photo 38 was taken at head of one of gullies at right. (Poesen Gully Index: P1). **b** Google Earth © imagery dated 30 August 2012. Gullies have not enlarged and are healing through vegetation, but parabolic dune at right has advanced inland before being converted to transverse dune ridges. Google Earth ©

there is severe rill and gully erosion from Merca to Mogadishu, a zone where the vegetation is highly degraded.

A deeper appreciation is needed for this remarkable feature and its importance to rangeland and pastoral systems. The use of modern analytical techniques, such as Optical Stimulated Luminescence Dating (OSL), will assist in establishing the chronological framework necessary to determine its environmental history.

The coastal sand belt has a rich and varied vegetation cover with plant communities on mobile and fixed dunes (Pichi-Sermolli 1955), and a serious debate should be made concerning any future ideas for extracting minerals from the sands that would likely disturb the biodiversity of this important pastoral region.

14.9 Case Study: Soil and Water Conservation and Vegetation Arcs in Somalia

14.9.1 Background

The authors have made use of archival materials, recent imagery and reports of contemporary travellers in the north to examine aspects of two distinct land cover types—enhancement of indigenous rainfed water-harvesting lands in the Arabsiyo catchment area and vegetation arcs that still cover large areas of Northern Somalia and the Ogaden.

b

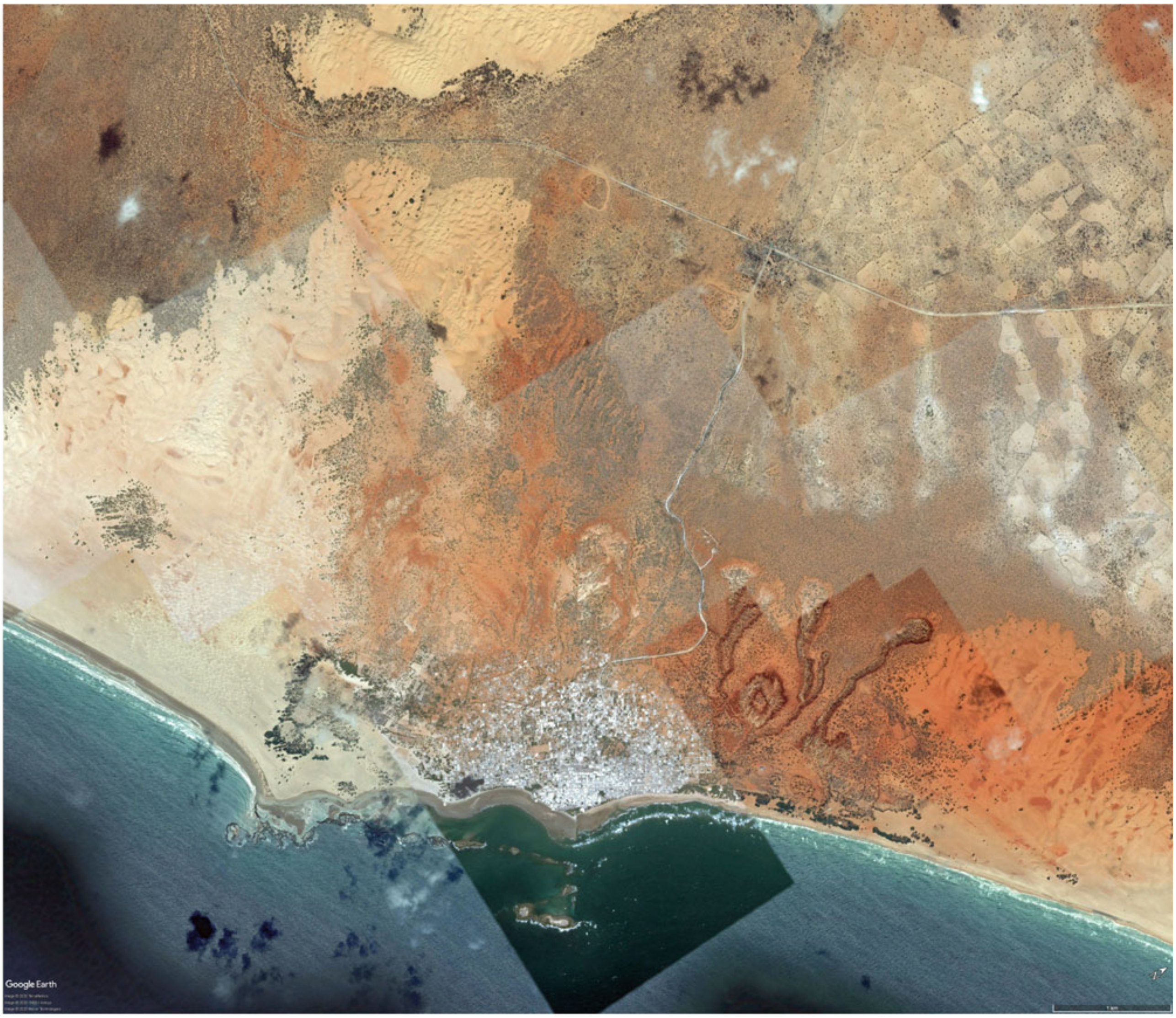

Fig. 14.35 (continued)

14.9.2 Arabsiyo Valley Soil and Water Conservation, 1963–64

The USAID implemented a project in Northern Somalia, now Somaliland, in the early 1960s. The Arabsiyo Valley was chosen as a pilot project. On the adjacent plains, the project constructed some 2800 earth bunds, whereas contour earth dykes, in total amounting to 380 km, were made by bulldozer to utilise the meagre rainfall (then 450–500 mm) within fields and control field erosion and reduce headward erosion of gullies.

In the late 1940s, the Somaliland Agricultural Department had started soil and water conservation measures and devised a system that would hold water but allow large storms to pass with minimal damage. The WB (1981) reported that "earth bunds, up to 120 m long and 1 m high on a 2 m base, were built along contour lines. Each bund was turned uphill at its tail end for a vertical distance of 30 cm above the base contour allowing 30 cm of water to be trapped. Each bund was set 60 cm higher than the bund below and field slope varied from 1 to 6%. Lands with a slope of 2% received bunds 30 m apart; and about 300 m of bunds would be needed per ha. In 1954 a bunding hire service was set up with pairs of oxen pulling scraper boards. The scheme offered bunding services free of charge provided they were matched by a similar number of teams operated by the farmers". The scheme was very popular, and the USAID project of new bund construction started in 1963, with tractors replacing oxen.

On the USAID project, a number of reports were written by Calvin Wixom (Wixom 1963, 1964). In the 1963 annual report, an oblique image was shown of the Arabsiyo Valley Soil and Water Conservation Project, reproduced in

Fig. 14.36 Ground photo of rills and pinnacle erosion of ancient sands on edge of gully above Brava. $CaCO_3$ soil concretions occur in the sandy clay loams–sandy loams of the relict aeolian dune soils below 3 m. *Photo* Munro ©, 1985

Fig. 14.44a. Using Google Earth, we are able to repeat this view in an image dated 23 November 2015 (Fig. 14.44b). The view taken by Wixom was towards the east and from about 9.561600°N, 43.69700° (some 14.4 km SSW of Arabsiyo and 40 km due west of Hargeisa). The landscape is a weakly dissected undulating plateau on the Cretaceous Yessoma Sandstone. On the plateau, there is a pale-coloured surface pan over a deep, dark brown soil. There is a marked change into paler bedrock of the Yessoma, shown as pink in the image. The main streams have become wooded, but a badlands zone, called *kerrib* in Sudan, and actually on weathered bedrock, remains largely unvegetated. Zooming in with Google Earth, one can observe that the edge of the soil cover on the plateau is, not surprisingly, still being gullied in parts (Fig. 14.45) but in general the steep sloping lands appear more vegetated. On the undulating plateau lands, the fields are aligned along the contours and show that the USAID project structures remain extant and appear to be maintained. In places, some fields appear to have been afforested.

The project, that ran from 1963 to 66, was reviewed by McCarthy et al. (1985) 17 years after it ceased, and this assessment was also incorporated in a general review of USAID projects by Erdmann (1993). The purpose of the Arabsiyo bunds was to improve soil moisture availability, increase infiltration of rainfall, decrease sheet and gully erosion; increase natural regeneration along barriers and increase soil organic carbon (SOM). Erdmann (1993) noted that impacts of the bunds on yields were evident after the first season, with sorghum yields doubled in the early years of the project: from 700 kg/ha to 1400 kg/ha (McCarthy et al. 1985). This doubling of the yield gave a typical farmer some 2100 kg surplus sorghum. The following is from McCarthy et al. (1985): they noted that at the time of the evaluation, farmers reported that production in treated areas was still significantly superior to that of non-treated areas, and indeed, yields were still 40–60% higher in the fields with the bunds. Another effect of the bunds was to increase sorghum stover production and, consequently, fodder for the livestock; after the project departed, a lucrative market for

Fig. 14.37 Use of *Opuntia* helps stabilise the Brava dunes by reducing impact of erosive rainfall on the sands. Above Brava. *Photo* Munro ©, 1985. Ground repeat photography cannot be made at present

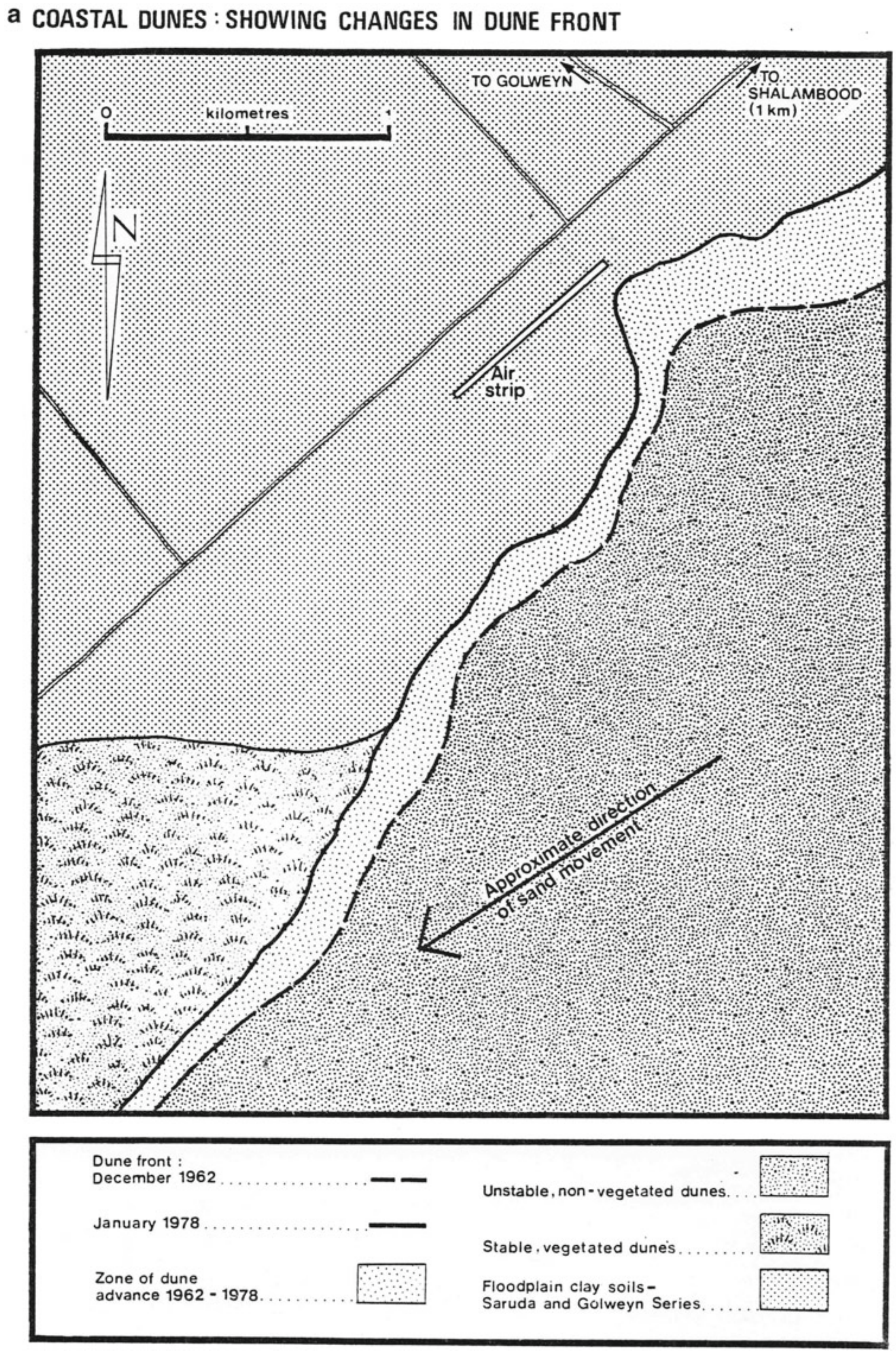

Fig. 14.38 **a** Dune fronts in 1978. Observations made by KJ Virgo, Fig F.1, Annex I, Soil (MMP, 1978a, b). Report archived at WOSSAC. **b** Google Earth image of same situation today. Google Earth ©

Fig. 14.38 (continued)

chat (*Catha edulis*) was initiated, and many farmers subsequently converted their food crop fields into *chat* plantations; 17 years after the end of the project, maintenance of the bunds was described as spotty and only the largest breaches in the structures appeared to have been repaired; maintenance of these earthen structures was described as demanding.

The WB project appraisal (1976) of the NWADEP agreed that bund construction by tractors was appropriate, but complementary use of oxen could be supported by favourable credit terms to farmers who opted for it. It suggested that a general reduction in bund height from 1 m height could be made in most parts. Further in the WB's Economic Memorandum (WB 1977), the expansion of the bunding project with WB funds was regarded as a priority area. The USAID-funded initiative was discussed by Reij et al. (1988) who said that the NWADEP was also using bulldozers to create the 1-m-high bunds (Abdi 1986; Critchley 1987).

Since then, this form of water harvesting has been extended over a very area of country to the west and south and extends into Ethiopia also as far as Jigjiga. South of Gunbarah these cultivated strips merge with linear patterned terrain, variously NNW-SSE and N-S aligned, that are natural vegetation arcs. Some of these contain farmsteads with water harvesting in the valleys, and on lower slopes of hills, water tanks have been constructed to harvest run-off.

On the rangelands of the Somaliland plateau, the future of livestock and range management was investigated by Hartmann et al. (2009) and most recently by Pfeifer et al. (2018). The latter noted that climate change is reducing the availability of biomass for livestock, while human behaviour is further reducing biomass production. The loss of animals in rangelands has resulted in pastoralists enclosing parts of the range for rainfed cropping and blocking of transhumance routes to water points. Vegetation arcs will suffer also. Land degradation is widespread in the country and involves soil erosion on unprotected lands, loss of vegetation by grazing, deforestation mainly for charcoal. Land use planning policies that aim to manage the region are formulated (Somalia Ministry of National Resources 2013) but need updating: in a region likely to suffer adversely from ongoing climate change, a more pragmatic participatory rangeland management approach is required. This can include changes such as restricted access to rangelands in wet season and catchment-based SWC interventions. This later was the approach of USAID in 1960s at Arabsiyo. Pfeifer et al.

Fig. 14.39 **a** Shalambood area. 17 December 1962. 1:30,000. *Source* RNMunro AP archives donated to NCAP. **b** The SW edge of the Genale scheme. Dunes at bottom left have been completely stabilised and road alignment unchanged since 1962. Google Earth ©

a

(2018) warned also against using high-resolution imagery without fully understanding the methods of the informal and closed information systems in pastoral communities. We can add that the late Dr Murray Watson, a pioneer in Africa of using oblique photography from low-flying light aircraft to identify households, livestock and wildlife (Watson et al. 1979; Watson 1982, Watson and Nimmo 1985), always backed up his flying with simultaneous ground surveys to verify the sampling strategy, the ecological strata and the statistical methods that produced the data sets from these strata. Modern high-resolution imagery is able to duplicate, at lower costs and more frequent passes, the photographic/imaging part of the RMR methodology. Future practitioners, using drones no doubt, should adopt similar rigour in identifying ecological strata, but making the ground verification is currently difficult.

14.9.3 Vegetation Arc and Water Harvesting in Somalia

The vegetation patterns or arcs of Somalia have long fascinated ecologists and biogeographers. The vegetation associations were first reported by Gillett (1941) who did not

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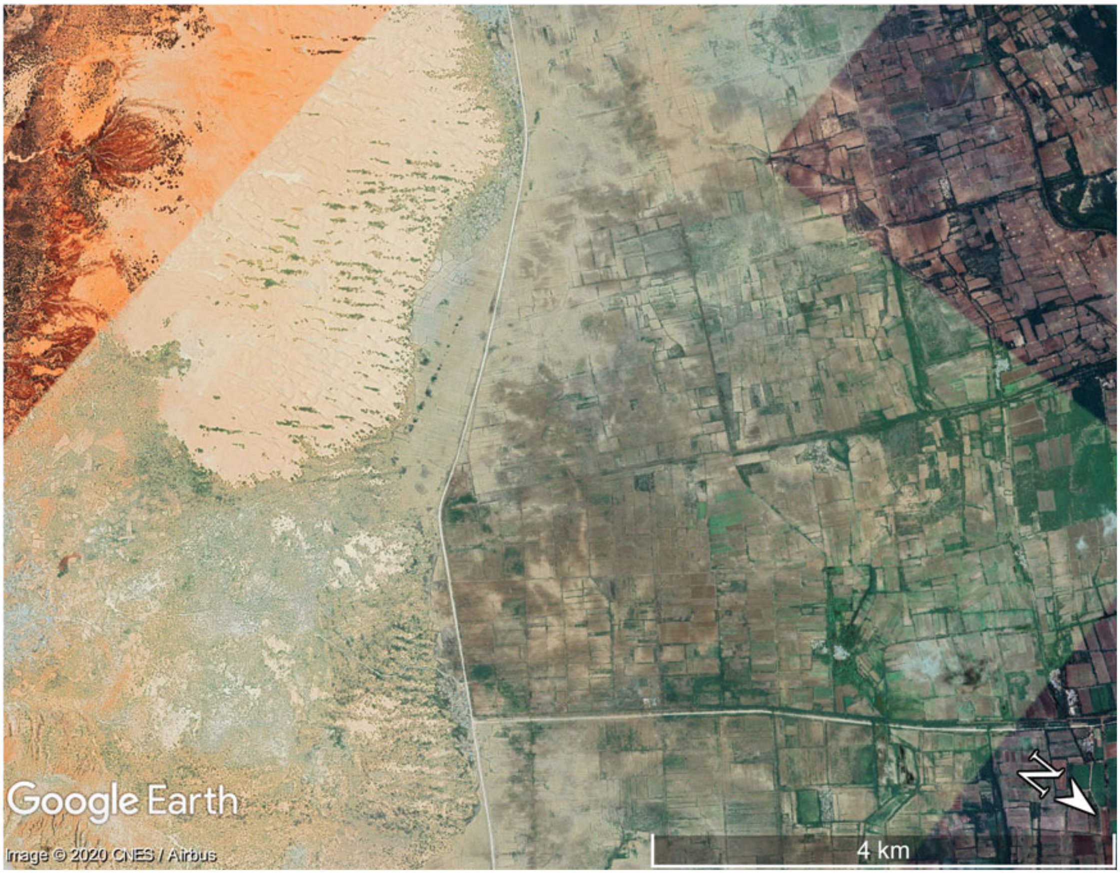

Fig. 14.39 (continued)

have the advantage of aerial photographic cover or flights, and their extensive distribution was first reported by Geologist W. A. Macfadyen (1950) who utilised USAF Trimetrogon oblique photography and then made ground checks to describe the process. The DOS 1:125,000 maps of Somaliland used RAF AP flown 1946–1955 and record the presence of vegetation arcs.

The vegetation arcs of Somalia comprise shrubs and bushes and are different in composition but likely of similar origin to the grass patterns in Sudan described by Worrall (1959) in the Butana area, and by Wickens and Collier (1971) in Kordofan; in Somalia other papers followed (Boaler and Hodge 1962, 1964; Hemming 1965). A global study of patterns, including North America, Mauretania, Niger, Mali, Saudi Arabia and Jordan by White (1970, 1971), summarised the mechanisms by which they formed: the arcs occur on gentle slopes in the 125–300 mm rainfall zone—thus a much more drier zone than the water-harvesting field patterns shown in Fig. 14.44 and 14.45—and are not formed by addition of windblown materials as the vegetation under the arcs grown on soils is higher in clay and permits greater moisture penetration than the bare aprons between each arc. The bare area is a run-off zone for water and eroded clay + silt material, and the arc then appears to migrate up-slope. With woody vegetation, this will be slow. Boaler and Hodge (1964) considered that the Somali arcs represented the degraded residues of more extensive cover in a former wetter climate, but presented no data to support. The regular symmetry of all these arcs, not just in Somalia, with orientation at right angles to direction of water flow and ground observations that they are active with species zoning, would suggest they are a natural feature of the Sahelian region. The remaining Somali arcs lie outside the rainfed agriculture zone and so are not at risk of being ploughed up. They are important to pastoralist communities who appear to utilise them carefully in Somalia and the neighbouring terrains of the Ethiopian Ogaden. This is an encouraging indicator of land being protected and preserving carbon in a fragile landscape.

Macfadyen (1950) used USAAF Trimetrogon ("TMG") photography flown in March 1945 by the 19th Photo Charting Squadron (19CS) that flew B-24 Liberators converted to photo-reconnaissance at 23,000 ft with simultaneous exposures of one vertical and obliques to left and right. Figure 14.46a, from Macfadyen (1950), shows TMG right oblique #61 of roll 283. The TMG films are at the US National

a

Fig. 14.40 **a** Xaafuun lagoon and Ras Xaafuun headlands in 1958 (RAF photography). Scans made of one large HSL mosaic print. Ref: Block 4, Sheet F13, 1:60,000, RAF 1958 photography. *Source* RNMunro AP archives. During 2020, the original negative will be donated to NCAP, Edinburgh, UK. **b** Ras Xaafuun and Hordio lagoon. Google Earth imagery 2012–2019. Slightly different orientation than Fig. 58. This entire coastline was struck by the 26 December 2004 tsunami. Sands stream onshore from the south (left), from coastal source-bordering barchan dunes and sand sheets that then move north for 65 km, along a "sand corridor" before re-entering the ocean to the north. The westerly edge of drifting sand backed up against old coastal cliffs on Miocene Limestone is quite clear. Google Earth ©

Archives. The view today on Google Earth shows a view that appears essentially the same (Fig. 14.46b) except for several prominent vehicle routes of today. Of course, a detailed examination is needed on the ground or vertical aerial photography to assess vegetation change more precisely.

In the Hiraan area of the Central Rangelands of Somalia, west of the Shabelle, are entirely indigenous traditional small-scale water-harvesting systems known as *Caag* and *Gawan.* These are practised by agropastoralists and on slopes over 0.5%. (Reij et al. 1988; Reij 1991; Critchley et al. 1991, 1992a, 1992b). Rainfall in Hiraan amounts to 150–300 mm and the system has developed over several decades to grow food crops (mostly sorghum but with cow peas) in response to drought. The *Caag* involves diverting run-off into basins with guiding arms. The *Gawan* is more of an *in situ* system with rainfall concentrated in small basins on flatter slopes with less run-off fed. West of the Shabelle natural vegetation arcs are found on the plateau lands, and a typical view is shown in Fig. 14.47a, copied from a 1:60,000 mosaic made from 1958 RAF aerial photography by HSL in 1960. Examining Google Earth imagery in an area some 38 to 45 km NW of Bulobarde, there are numerous enclosed fields set within extensive vegetation arc belts. At 4.121490 N, 45.26270 E and 188 m asl, for example, what appears to be a *Gawan* system has been developed on very gently sloping lands of natural vegetation arcs (Fig. 14.47 b), and this may be how the system has developed in general, as discussed above. Examples of *Caag* with longer run-on zones are common in valley lines.

In another area, the situation in 1958 is shown in Fig. 14.48 a, from a 1:250,000 scale mosaic. The same area has been examined on Google Earth (Fig. 14.48b); an enlargement (Fig. 14.49) shows woody vegetation on the arc that indicates a permanency and long life of many of these features, while on other adjacent arcs the woody vegetation has disappeared. The settlement is some 56 km NE of Qardho and 980 km NNE of Mogadishu in the Bur Aden hills (Google Earth © 2004 imagery). The impression from

b

Fig. 14.40 (continued)

studying these images is that they appear much the same and cover vast areas of Somalia and the Ogaden in Ethiopia. In making closer look by zooming in with Google Earth, it is apparent that shrubby and arboreal vegetation, often 10 m in diameter, are common. Locally, there is degradation and vegetation has disappeared. That much remains is encouraging for the maintenance of biodiversity in these drylands. It is interesting to find views of Earth, from the Somali deserts, that appear to look unchanged, but closer examination does show there have been modifications to the band widths of arcs and general degradation where human activity has increased. These deserve more study on the ground.

The mechanism of arc formation has been addressed in a number of mathematical modelling studies made over the past twenty years (e.g. Valentin et al. 1999; d'Herbès et al. 2001; Sheratt 2005; Borogogno et al. 2009; Deblauwi et al. 2012; Foti and Ramirez 2013; Chandrasekaran 2017; Gowda et al. 2018). Substantial change was attributed by Gowda et al. (2018) to the increases in human activity, and they conclude that mathematical modelling can account for the creation of arcs by an interactive process of self-organisation between vegetation and rainfall run-off. Further, they noted that bandwidth is shown to increase in some areas, and thus the vegetation cover is greater. In areas where there has been minimal human interference, the bands appear much the same. The change is thought due to species composition changes due to human pressures. The review by Valentin et al. (1999) is particularly useful, and the authors note that arcs form in rainfall zones of 50–750 mm; slopes range from 0.2 to 2.0%; dust is likely to add fertility to the soil and thus leads to the increases in biomass; they act as natural bench structures or terraces to control soil erosion; and the whole ecosystem including bare areas and the vegetation bands is highly resilient to climate change and is thus, crucially, self-sustainable. Some workers consider that these were part of a once more extensive vegetation cover that has degraded as the climate became drier. Evidence for this is not yet proved, but attempts to afforest the bare inter-band areas

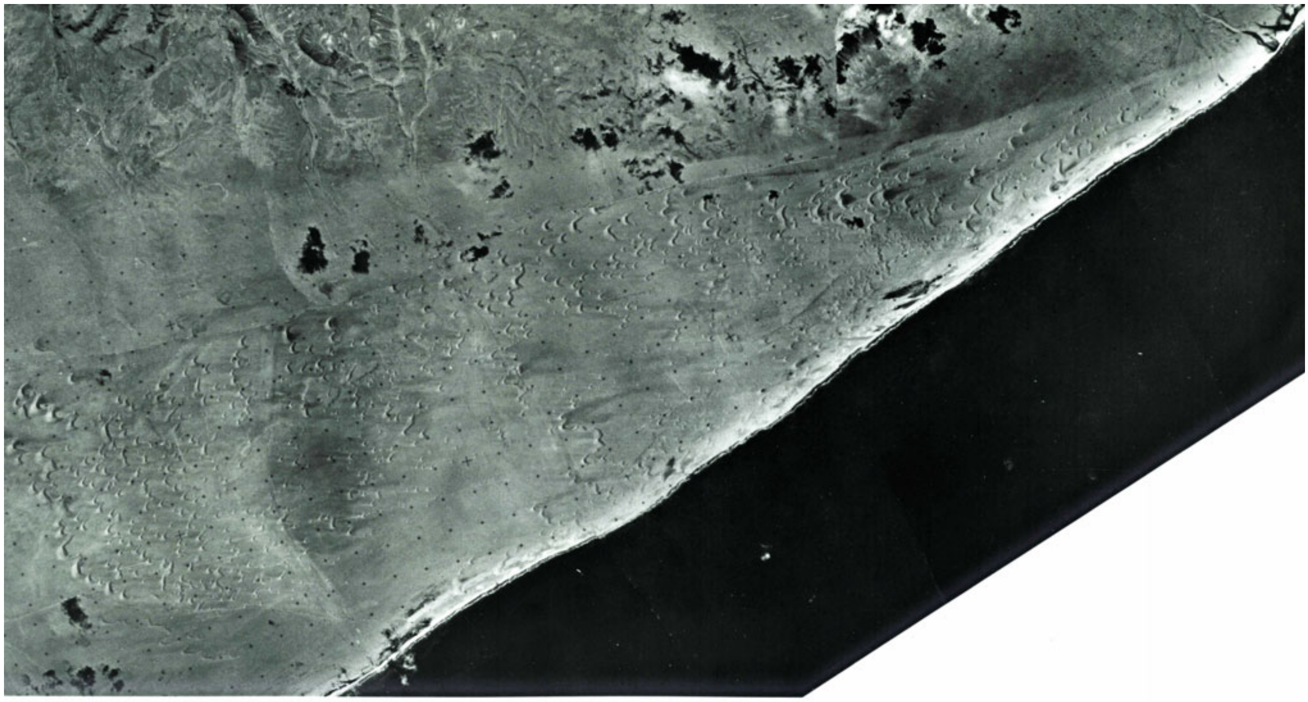

Fig. 14.41 HSL mosaic of Northern Somalia, Block 4, sheet G-13, 1:60,000 scale. The interior westerly edge of the "sand corridor" is clearly visible against cliffs of Miocene Limestone. The barchan dunes march across the coastal plain only to re-enter the sea at extreme right on this image. *Source* Munro AP archives. During 2020 the original negative will be donated to NCAP, Edinburgh, UK

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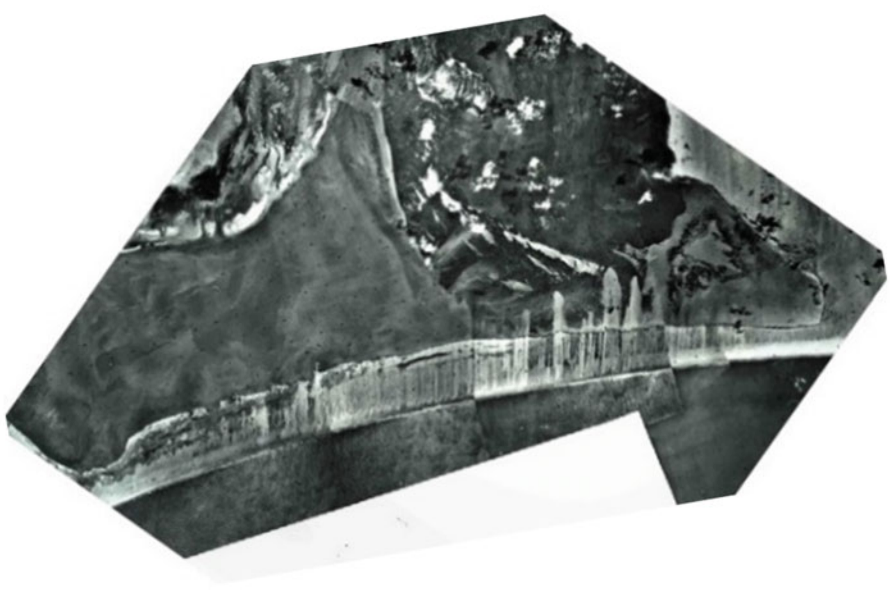

Fig. 14.42 **a** Close-up—RAF 1958 photography mosaiced by HSL in 1970s. *Source* RNMunro AP archives. During 2020, the original negative will be donated to NCAP, Edinburgh, UK. **b** Close-up 2015. Onshore movement of sand shows same wind direction. This low-lying strand was devastated by the 2004 tsunami. Google Earth ©

b

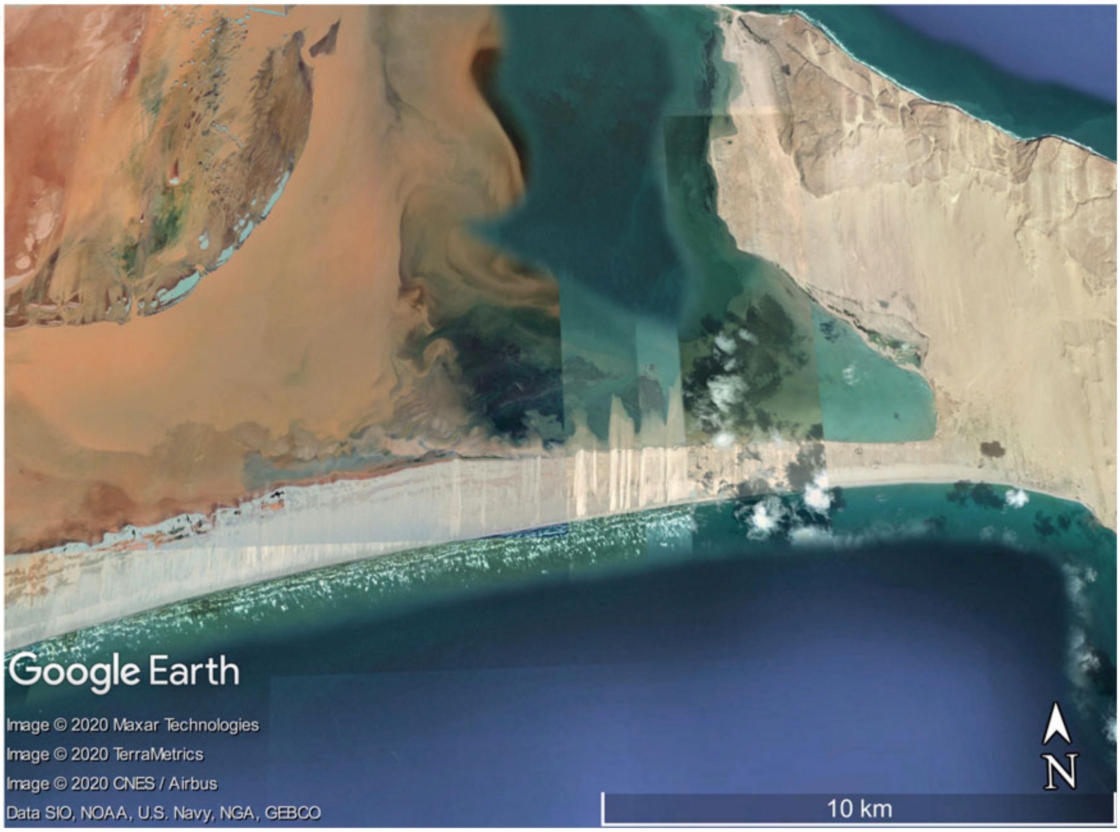

Fig. 14.42 (continued)

often fail and lead to an increase in degradation of the land under both the planted trees and arcs, as moisture is less available.

Since 2004, Munro has made observations in the Butana of Central Sudan where the bands are of grass and has used Trimetrogon photography to examine the change (Munro et al. in preparation for DAI, Berlin). The grass patterns of the Butana and Kordofan (Worrall 1959; Ruxton and Berry 1960; White 1971; Wickens and Collier 1971) remain in a few places but since the 1970s much has been ploughed up and the grasslands converted to rainfed sorghum cropping. The erratic nature of the rainfall, however, is such that cropping can often fail, and a valuable grazing resource has been degraded: a double failure of the land use planning regulatory process.

In other countries though—e.g. Australia and Niger—decision-makers and land managers are aware of the importance of these natural systems for soil and water conservation, water harvesting and maintenance of nutrients in the soil (Kusserow and Haenisch 1999). In Northern Somalia (Somaliland), the water-harvesting terraces (shown above) and indeed very similar features, the *teras* (van Dijk 1993), on the Inter-Riverine zone of the Atbara-Gash rivers near Kassala in Sudan, are likely to have been developed by early farmers in many marginal semi-arid areas to copy-cat the ecosystem of the vegetation arc. In the lands west of the Arabsiyo study area in Somaliland, and extending into the Ethiopian Ogaden towards Jigjiga, there is a gradual change from water-harvesting structures to vegetation arcs and linear features of various shapes. The inference is that in this region, the natural vegetation was gradually displaced by crops—notably sorghum and millet, while in the lower rainfall and less populated areas of the Ethiopian Ogaden and Somali Haud shrubby bushland has survived in the arcs.

a

Fig. 14.43 **a** USAF Trimetrogon K-17 right oblique aerial photograph from 1945. Shows the Ferio Range. View looking south onto the Haud. Cretaceous Yesomma Sandstones pass up in Eocene Auradu Limestone capped by Taleh Evaporites and Dolomites. *Photo Source* Govt of Somaliland, 1954. **b** Approximately same view of Ferio Range with Somaliland plateau in background. Oblique from a point some 40 km East of Berbera. In such very arid areas, floods are rare and the landscape appears timeless. Google Earth © mosaiced images dated 27 May 2013 and later

14.10 Conclusions

14.10.1 Water Harvesting

In NW Somaliland, a suggestion was made at the 1986 workshop on water harvesting (Critchley 1987) to establish fodder banks and trees in this region using water-harvesting technology on the bunded strips. Google Earth imagery now shows the presence of numerous wooded strips, and the arable landscape has changed for the better.

The Somalia contribution to the Global Forest Resource assessment (FAO 2014) noted that Mesquite, *P. juliflora* (and the very similar *P. chilensis)* is dominating large areas of sands along the coast. *Prosopis* seedlings for sand dune fixation had been introduced by the National Range Agency prior to the outbreak of the civil conflict (Zollner 1986; Fagotto 1987; Bowen 1988; Pye and Tsoar 2009). One should note though it was one of various other species, mostly local, that were being used. Due to lack of control in planted areas, and the attraction of the Mesquite's highly nutritious seed pod to goats and other livestock, it spread uncontrolled over huge areas. Sand stabilisation was a common reason for the introduction of *Prosopis* in many countries, but foresters forgot the recommendations made in the Sudan by FAO-UNDP (Bosshard 1966; Wunder 1966)

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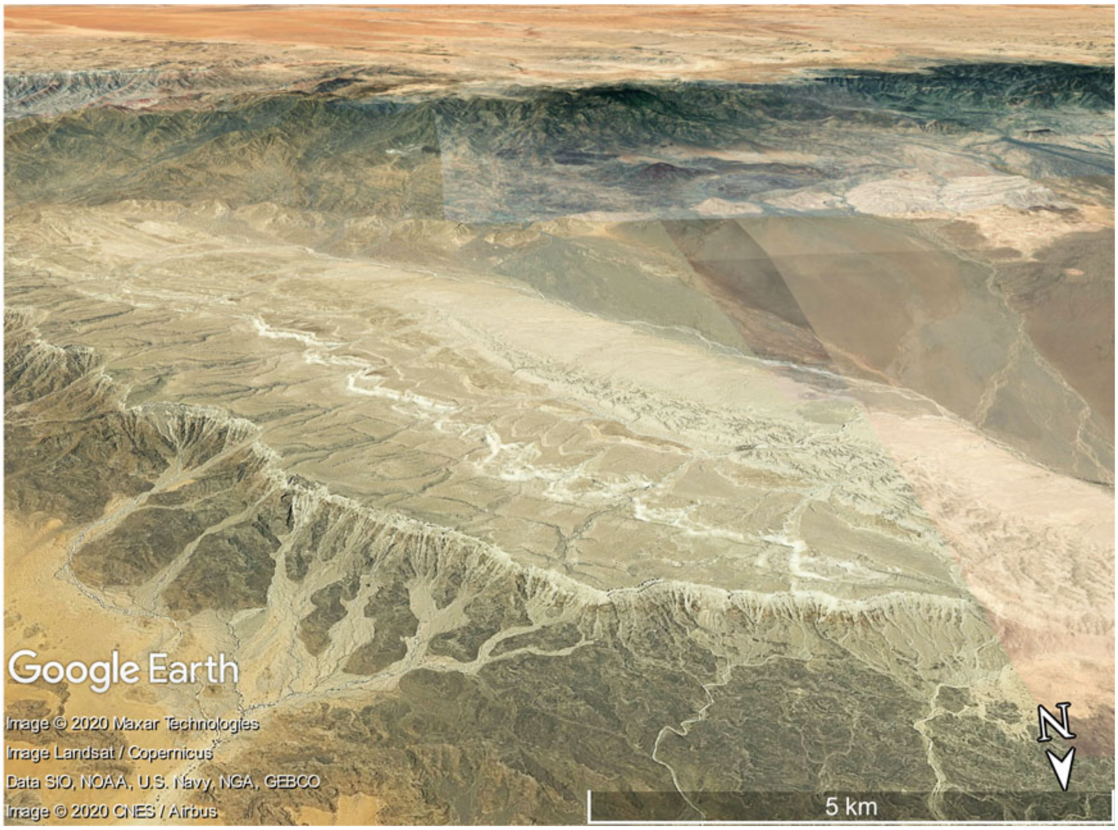

Fig. 14.43 (continued)

that it could spread easily as a serious weed unless carefully managed. Unmanaged this voracious invasive plant has spread and out-manoeuvred native flora.

Meroni et al. (2017) reported on the invasion of the exotic tree mesquite *Prosopis juliflora* in NW Somalia and its possible threat for farmland, but that it is confined mainly to the non-arable steep lands, and it has not spread onto the bunded farmlands by livestock who have eaten the seeds: it is controlled by farmers here who know that if a seedling is extracted within a week or two after emergence it will not survive and re-emerge elsewhere. The long-term answer is to manage *Prosopis* by (medicinal) charcoal manufacture, closed access and milling of seed pods as a food for livestock and communities. In some areas of Sudan, for example, these practices were developed in the 1940s and are being reintroduced after a long gap.

a

Fig. 14.44 **a** Oblique of the Arabsiyo Valley and gully edge (from Wixom 1963). **b** Arabsiyo Valley repeat, using Google Earth ©. Image dated 23 November 2018

b

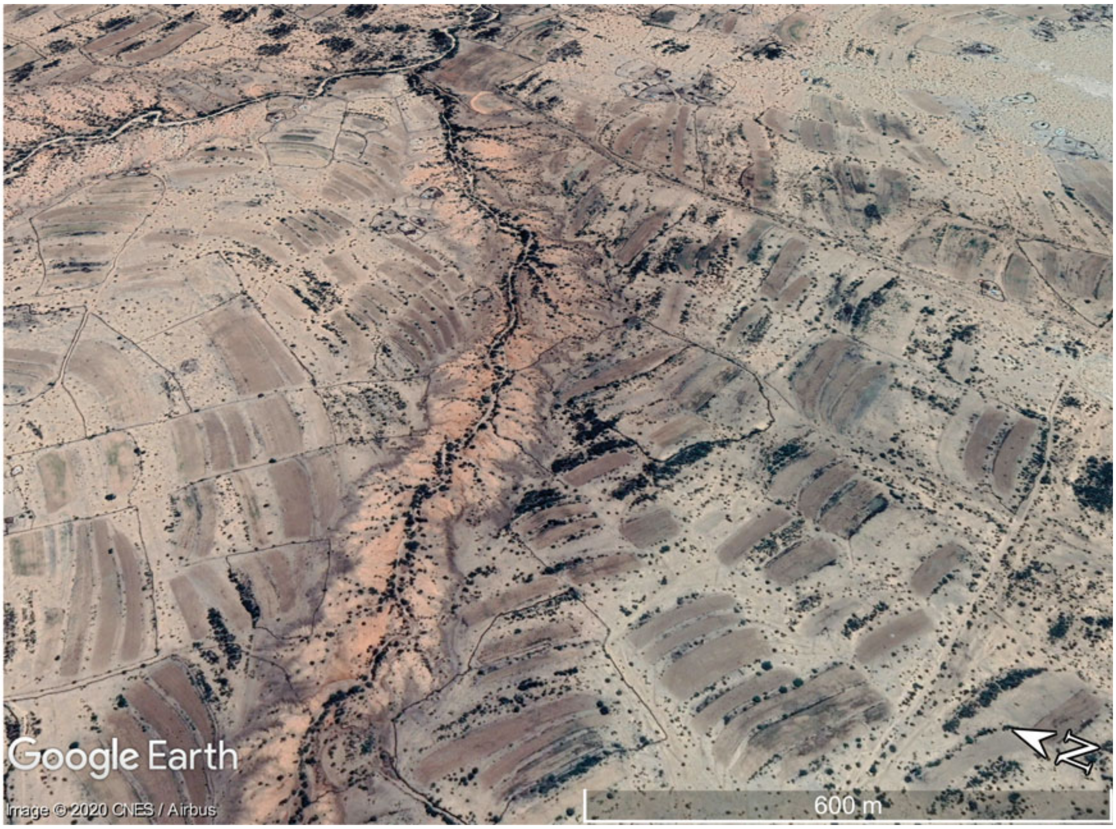

Fig. 14.44 (continued)

Fig. 14.45 Enlargement of part of the Arabsiyo. The contour bunds introduced by USAID in 1960s remain extant and much more widespread as work has been replicated. Headward erosion onto the plateau is reduced. 23 November 2018 Google Earth ©

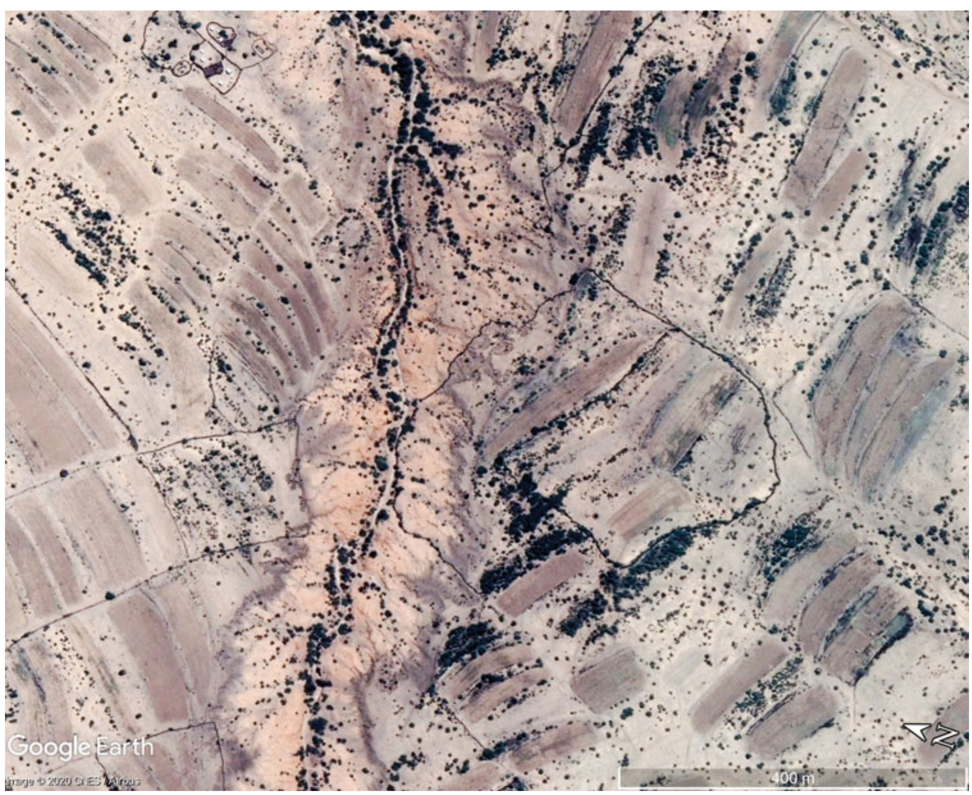

Fig. 14.46 **a** USAF Trimetrogon 1945. Roll 283 R61. This is an oblique right view, facing south, of the Dufea'au area. © Royal Geographical Society, 1950. Reprinted from Macfadyen, 1950 with permission of the RGS. Original Trimetrogon images are available from US National Archives. **b** Google Earth imagery and Vegetation arcs—Dufea'au area. The view is remarkably similar. Groundwork could determine if vegetation is same. Google Earth ©

14.10.2 Vegetation Arcs of Somalia and the Ogaden

In the drier areas of Northern Somalia, in the Ethiopian Ogaden and to the Juba at Luuq, vegetation arcs and patterns appear to be surviving over extensive areas. This is encouraging. We notice a gradual change or evolution into water-harvesting field systems, where rainfall becomes higher which suggests that water-harvesting systems for agricultural use originated when early farmers seeking to grow crops in these dry areas understood that the natural process of vegetation arc formation could be adapted for arable use and thus mimicked nature. Archaeological investigations could help understand their origins. In general, though, much needs to be done at all levels of management to understand and preserve these extraordinary ecosystems in a changing world. While assessments of land cover change, such as made by Pricope et al. (2013), provide

b

Fig. 14.46 (continued)

a broad picture over a vast area of the Horn of Africa, the sample areas did not cover any arc area in Somalia, and this needs to be addressed with supporting studies in the field.

14.10.3 Northern Escarpment

Due to the closure of the AP archives during COVID-19, we were unable to examine any vertical or oblique aerial photographs of the remarkable mist forests along some 300 km of the Golis Range on the north-facing Somaliland escarpment, but this area lends itself to a future repeat photography study. Trimetrogon photography in particular provides the means to do this. The escarpment lies between the longitudes of Berbera and Bosaso, at elevations of 1000–2400 m above sea level and benefits from moisture-laden clouds brought inland by monsoon winds off the Indian Ocean. It is very similar to the mountains of Dhofar in Oman where in places a dense arboreal vegetation exists. The Golis Range forests comprise some of the important remaining centres of biological diversity and species endemism in Somalia, but civil war and lack of control have led to some degradation of these forests (see Box 2 in Min. of Fisheries and Marine Resources 2014).

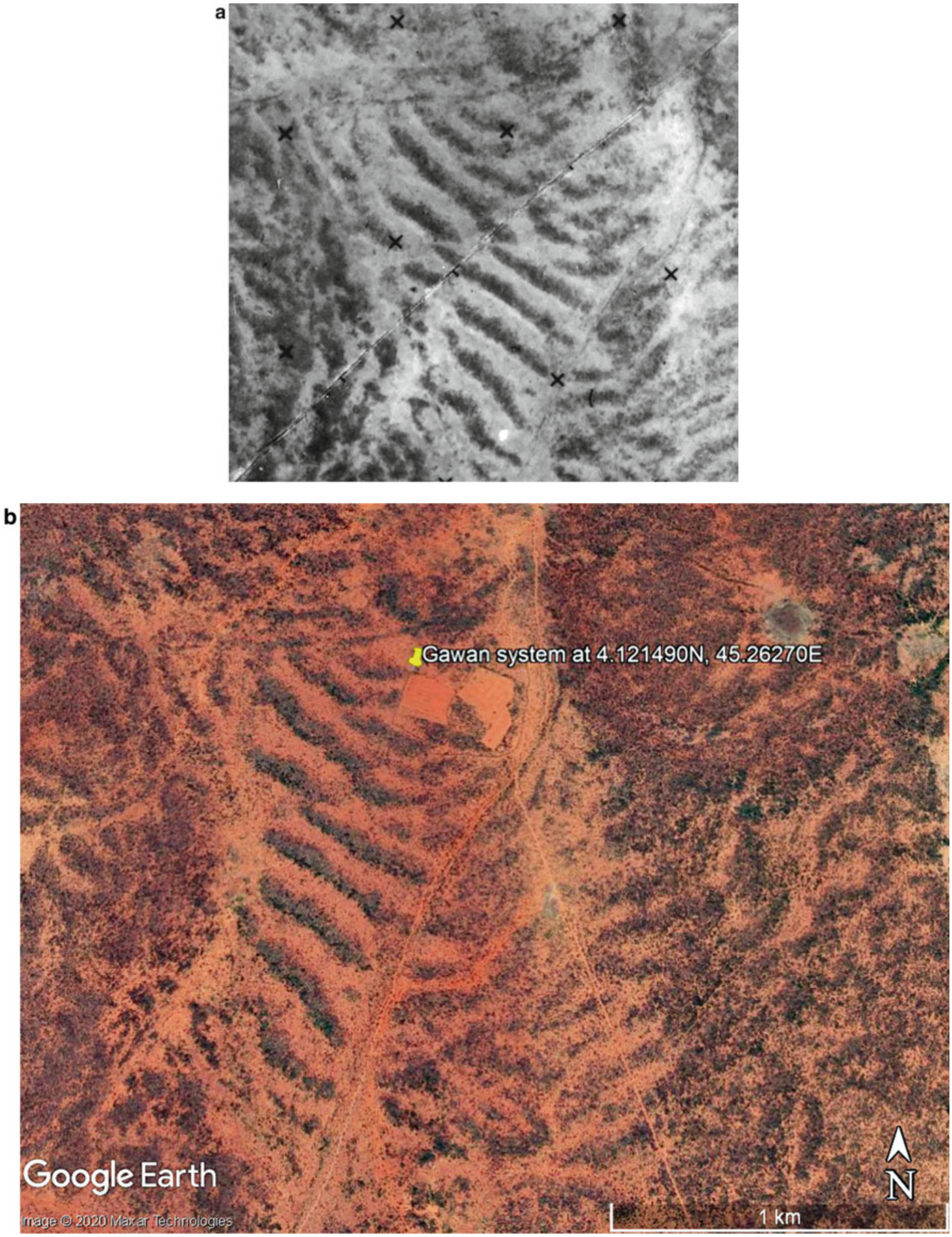

Fig. 14.47 **a** Vegetation arcs in Central Somalia 45 km NW of Bulo Barde. 1958 RAF photography. The line from top right to bottom left is the join between adjacent APs. Copied from negative mosaic at 1:60,000 scale made by Hunting Surveys for the FAO land and Water Surveys (Mosaic Series D-5890, Sheet 17). Same area is shown in Photo 55. *Source* Munro AP archives. During 2020, the original negative will be donated to NCAP, Edinburgh, UK. **b** Water harvesting in Central Somalia 45 km NW of Bulo Barde. Shows conversion of vegetation arcs to *Gawan* basin system of cropping. Vegetation arcs remain largely the same as 1958

a

Fig. 14.48 **a** From 1:250,000 scale HSL Mosaic made in 1973 using RAF 1958 vertical photography. *Source* Munro AP archives. During 2020 the original negative will be donated to NCAP, Edinburgh, UK. **b** Same area Google Earth 7 March 2004. Google Earth ©

14.10.4 Use of Archival Materials

A pertinent and interesting point made by Erdmann (1993) was that for a thorough case study review, examination of project and (in that case) USAID Mission literature is essential, but as much of this information is grey matter literature, it will be "difficult to make a reference collection": the archives at WOSSAC and SWALIM have done much to redress that sort of information gap.

This assessment has used archive materials, many carefully kept for 40 years. Although the civil war led to loss of most of the archives in Somalia, a large number of documents have long been stored in the WOSSAC archive, and FAO-SWALIM has sought out materials in other countries.

SWALIM also has georeferenced archival soil studies and with limited fieldwork in the south analysed new soil profiles during 2007 in the Juba and Shabelle. Vargas et al. (2007) noted that while remote sensing can be very useful in

b

Fig. 14.48 (continued)

examining land cover and land use over the soil, it has limitation if one wishes to examine, for example, soil depth: this is of course quite true! Soil and vegetation surveys on the ground are essential; groundwater is best assessed by drilling water wells and modelling seasonal changes. Vargas et al. (2007) also said that some of the soil survey data from 1968 through 1985 that could locate soil sites had been lost, but in fact we believe most of the key studies are available in the WOSSAC archives: that is all for the future to make more detailed reviews.

The online archive at WOSSAC with only 17 items digitised out of a Somalia collection of 514 items represents an untapped resource to be digitised and made available. While some of these are available in SWALIM online, the originals should all be digitally captured at WOSSAC—funds are needed to digitise all materials that sit in the archives waiting to be scanned!

The present paper has introduced the use of a huge archive of Somalia mosaics, held now at the UK's National Collection of Aerial Photography. These need future funding for digitising, dissemination and a programme to assess change. The Royal Air Force AP films from the late 1940s through 1958 are available at NCAP, and an assessment of change over all of Somalia is possible.

There is a scope in this region for future assessments to utilise the archival AP and grey literature archives—the latter all too frequently ignored—to assess ecological change. There are various ecological baselines to re-examine, but obviously groundwork will be essential in any quantitative assessment of faunal and floral change. The assessment of the formation and history of the ancient dunes and sand formations requires a modern approach. Repeat photography using additional photographic archives including 1945 USAF Trimetrogon can be made. Soil sites

Fig. 14.49 Enlargement of a set of arcs from Fig. 14.48b. The settlement (at 9°38′46.18‵N, 49°34′15.52′E) is near the Bur Aden hills, some 56 km NE of Qardho. A pastoral area too dry for rainfed farming, tanks have been dug in the bedrock to harvest run-off. Woody vegetation occupies some of the arcs showing the stable nature of the arc, but some have lost their vegetation. Google Earth © 2004 imagery

have been georeferenced by SWALIM from the various maps made on the studies noted, above but additional sites on the Lockwood-FAO map can be georeferenced and re-examined to assess change in morphology and chemistry including soil organic carbon (SOC) in the rainfed agricultural lands; variations in soil salinity/sodicity; and variations to the quality and depth to subsurface water tables. The original Lockwood aerial photos with locations have been lost (one presumes), but careful use of the maps can relate the approximate location of sites for future analysis.

After the civil war in Somalia ended, considerable effort was made by donor agencies and NGOs to assist in the rehabilitation of the country, and a very considerable amount of grey literature is available online. While ground access has been possible over much of the north Somaliland and Puntland, the southern part, the Inter-Riverine area remains largely inaccessible for security reasons. The appraisal by SWALIM of land cover of the older development schemes in the south has largely based on remote sensing; the land cover maps shown in Monaci et al. (2007) did not appear to have used any of the land cover studies in the Inter-Riverine area (e.g. the studies by Madgwick 1988, 1989; MMP 1985), and also are of low resolution making it difficult to be used in a comparison with archival aerial photography.

An option in the near future will be to use drones for repeat views. At low altitude, these are often used at archaeological sites, but oblique repeats at a higher altitude (such as 20,000 ft, the height of the Trimetrogon) are feasible and may even be permitted. A repeat position can be located with Google Earth or equivalent and the oblique view coordinates fed into the photo-drone's flight plan. But the risk of anything flying being shot by foe or friend down remains high in Somalia. In this work, we have no more than just skimmed the surface of a remarkable resource of RAF aerial photography, a timeline of the state of the landscape of Somalia in 1958, and provided examples that show how the landscape has changed since then. Much more can and should be done to utilise the thousands of aerial photographs from earlier periods.

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