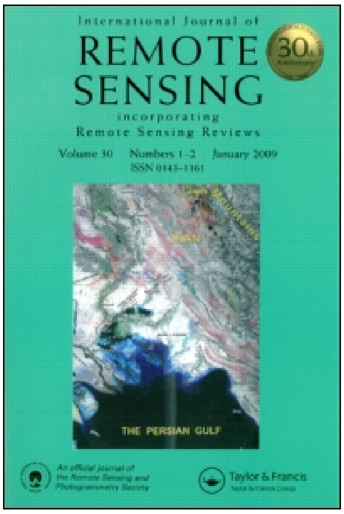

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The first detailed land-cover map of Socotra Island by Landsat/ETM+ data

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Present study has produced first detailed land-cover map of Socotra Island. A Landsat 7 ETM+ dataset was used as a main source of remotely sensed data. From numerous reference points (more than 250) coming from the ground data verification the set of training fields and the set of evaluation fields were digitised. As a classification method the supervised maximum likelihood classification without prior probabilities was used in combination with rule-based post-classification sorting, providing results of sufficient accuracy and subject resolution. Estimates of the area and degree of coverage of particular land-cover classes within Socotra Island have brought excellent overview on state of island biotopes. Overall accuracy of the map achieved is more than 80%, 19 terrestrial land-cover classes (including three types of Shrublands, three types of Woodlands, two types of Forests and Mangroves) have been distinguished. It consequently allows estimates of the current and potential occurrence of endemic plant populations, proposals of management and conservation plans and agro-forestry planning.

1. Introduction

Socotra Island is known for its high degree of endemism; even habitat loss has currently there rather hidden character given by permanent, long-term, though escalating overgrazing. Recent fast development of the island (e.g. road construction and urban development) together with expressive population growth can, however, change the character of human pressure on Socotran environment very quickly. All the past and present exploration activities on Socotra have brought a wealth of information documenting different aspects of the islands environment (e.g. Miller and Morris 2001). However, existing relevant map products did not match with such high level of knowledge. This, in turn, created severe problems for a well-prepared protection strategy. The new land-cover map of the Socotra Island can therefore offer so valuable and important detailed grounds for effective and relevant decision-making and management of local natural resources as well as for formulation of future conservation strategies.

The Land-Cover (LC) map has been created in the framework of a bilateral Czech-Yemeni project '*Creating an ecological network and agroforestry, educational and cultural doorway for sustainable development of the Socotra Island (Republic of Yemen—RoY)*' (Pavlis and Habrova 2001, Pavlis 2004), which has been realised within the Czech Developmental Aid Programme rendered to RoY. Objective of the

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project was to verify existing state of the island biotopes, delimitate ecologically important landscape segments and compose a proposal of the ecological network aimed to: (1) conserve endemic plants and animals (2) prepare basis for sustainable agroforestry management respecting conservational aims and acceptable by the local community.

Fifth framework programme of the European Commission (2000) stated, that traditional species-oriented and field survey methods of vegetation mapping and monitoring alone are incompatible with the increasing demand for precisely located spatial data of natural sites. Therefore the data and techniques of Remote Sensing (RS) have been used for the creation of the LC map.

Naveh and Lieberman (1984) point to numerous advantages of RS. One of the advantages of remote sensors is a synoptic overview they provide. Ground survey methods are obviously unable to achieve such an overview. A total scene is recorded as an image, not just the group of data points that ground methods can collect.

However, despite the considerable developments made recently, the accuracy with which thematic maps can be derived from remotely sensed data is often still judged to be too low for operational use (Townshend 1992, Wilkinson 1996). Several studies described the limitation of the conventional statistical image classification techniques such as the assumption of data in normal distribution, requirement of large training sample in a supervised classification that ultimately lead to the reduction of number of discriminating variable in dataset, etc. (Mather 1999, Tso and Mather 2001).

Numerous authors, for example, Molenaar and Janssen (1991), Shrestha and Zinck (2001) used the integration of additional information in classification process as a technique that is believed to out-perform the standard statistical classifiers as maximum likelihood and its aforesaid drawbacks.

Similar approach has been employed also in this study. Resulting LC map can help to fill the knowledge gap about the unique worthwhile natural area, where until now no satisfactory map of vegetation cover exists, as well as to fulfill aforesaid aims of the developmental project.

2. Study area

Socotra Island is the largest and most easterly island of the Socotra Archipelago, lying approximately 240 km east of the Horn of Africa and 480 km south of the Arabian Coast (see figure 1).

It is administratively related to Aden province, which is about 690 kilometres away from the island. While its geographical area is about 3600 square kilometres (Aitken 2000), and of 135 by 40 kilometres, it overlooks the Indian Ocean. It is regarded as the biggest of Yemen's 124 islands.

The area of interest can be more precisely located as an area between latitudes $12^{\circ}15'$ and $12^{\circ}45'$ N and longitudes $53^{\circ}15'$ and $54^{\circ}35$ E.

Environmental conditions and quality throughout the island are generally good and much better than those on the major part of mainland Yemen. Beydoun *et al.* (1970) geologically characterise Socotra as the island composed by plutonic nucleus of the granitic Hagghier Mountains located in its centre, and by two similar crystalline massifs at the eastern and western tips of the island, in places overlaid by sedimentary rocks, mainly limestone and sandstone. According to Kossmat (1907) two limestone plateaus probably correspond with similar layers on the nearby Somalian peninsula.

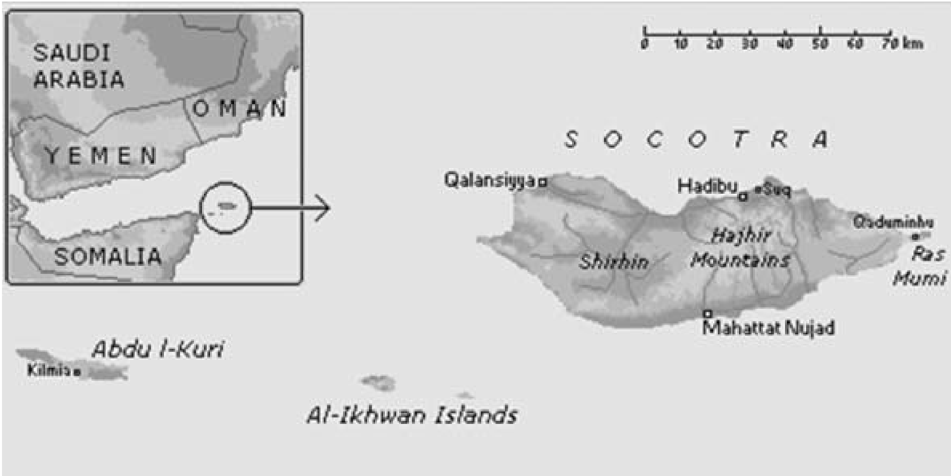

Figure 1. Location of the island of Socotra.

A sufficient set of climatic data is lacking; only scarce information for a few years in the 1940s and in 2000 (Pavliš and Habrova 2001) is available. Popov (1957) and Miller and Morris (2001) state, that the island generally falls into an arid tropical zone, but with a climate tempered considerably by north-east and south-west monsoons, it is less torrid than that of the adjacent mainland. Precipitation ranges between 200 mm for coastal plains and 1000 mm (estimate includes heavy horizontal rain-fall) for the highest mountains.

From a biogeographical viewpoint, Socotra is evidently more closely linked with Africa than Arabia. Its three main biogeographical zones can be distinguished as follows: (1) coastal plains varying considerably in width; (2) limestone plateaus ranging from 300 to 700 m altitude and extending virtually throughout the island. It is dissected by a number of deep valleys and steep escarpments and in places is bounded directly by the sea; and (3) the Hagghier Mountains in the centre rising up to 1519 m altitude.

Species diversity projected through altitudinal vegetation zones is markedly influenced by orographical, geological and pedological variability of the habitats. The prehistoric origin of local plants and their degree of endemism reaching some 35% (Miller and Cope 1997) rank the island among the most environmentally important spots on the Earth.

Naumkin (1993) says that the first inhabitants, represented by south-Semitic nomadic tribes, came to the island probably some 3000 years ago. Over many centuries they developed a relatively balanced land management system, securing self-sufficiency in food for a scarce population. As a matter of fact, grazing practice naturally influenced plant communities and notably contributed to the contemporary distribution and structure of tree populations around the island, including endemic *Commiphoras, Boswellias, Dendrosicyos socotranus* and *Dracaena cinnabari*.

3. Material and methods

3.1 *Data used*

A Landsat 7 ETM dataset (Path/Row 159/051) acquired on 29 April 2001 was used as a main source of RS data for the present study.

Digital Elevation Model (DEM), which was digitised from the British topographic map released by Royal Geographical Society (1978) was provided by the local UNOPS/EPA office in Haddiboh (Socotra Island). DEM was employed in a classification process as a source of ancillary data for rule-based post-classification sorting.

Thematic vector layers provided also by the local UNOPS/EPA office (e.g. fishing villages, geology layer, etc.) were incorporated in the rule-based post-classification sorting as well.

A set of 17 Ground Control Points (GCPs) acquired by GPS during the ground truth was used for geometric corrections. More than 250 reference points located by GPS were gathered during the field investigation in August 2002. According to these points two sets of reference fields (the set of training fields and the set of evaluation fields) were digitised.

3.2 *Geometric corrections*

As a first step, all the Landsat ETM data was georeferenced using 17 GCPs. It was not possible to gather more GCPs since on the surface of the island, there are no sharp features as crossroads or bridges (no presence of any pronounced infrastructure on the island) and, therefore, only natural distinct land-shapes as small distinct capes and inlets could be used. Accordingly, almost all GCPs are located on the seacoast around the island while inland points are (unfortunately) missing. Linear polynomial transformation based on 13 control points was used (4 less reliable points were omitted from the calculation) with overall RMS$=0.000186^{\circ}$, which is less than one pixel (30m).

3.3 *Classification*

During the exhaustive terrain survey which was performed in the first stage of the Developmental Assistance Project (1999–2001) lists of Groups of Biotopes Types (GBT) and Biotopes Types (BT) encountered on Socotra Island were defined (Buček 2001). Groups of biotope types differ above all by differences in the physiognomy and structure of vegetation. Biotope types are divided according to differences in the species composition of dominant species. This nomenclature was particularly taken into account in the current land-cover classification. Of course, the definition of LC classes had to be adapted so as to be separable from the RS point of view. Therefore some classes are on the level of GBT and other on the level of BT. Final nomenclature distinguishes 22 classes, after exclusion of Clouds and the Sea 19 terrestrial land-cover classes remains (see figure 3).

From numerous reference points (more than 250) coming from the ground truth verification the set of training fields and the set of evaluation fields were digitised. The two sets are individual although not completely separate since for most of the reference points a couple of fields was digitised—one training field for the creation of 'spectral signatures' and one evaluation field for consecutive accuracy assessment. Due to the spectral heterogeneity of most of the land-cover classes (influence of a sunny or shade aspect of slopes in mountain areas, influence of different parent rocks, etc.) multiple spectral signatures for particular classes had to be created. In this manner 37 working classes (spectral signatures) were created. These classes were reclassified in final 22 (19) LC classes after the classification process.

As a classification method the supervised Maximum Likelihood Classification (MLC) without prior probabilities was used. In the MLC classification some misclassifications between spectrally similar classes evolved. It was, e.g. the question of Built-up land which was often mistaken as Bare soil or Dwarf shrubland. It is understandable since dwellings are there built from local natural materials as stones or dry wood which are in fact physically (and so spectrally) identical with surroundings. Another common confusion appeared between classes G1 (over-grazed grassland on limestone plateau) and Gm (cleared montane pastures) and similarly between Dw1, Dw2 and W.

The differences in spectral reflectances among particular classes are indicated in form of spectral response curves (see figure 2).

3.4 *Post-classification sorting*

With a view to eliminate or at least restrict above mentioned confusions a rule-based post-classification sorting was applied. For the main it is the question of simple version of a Knowledge Base classification, which is understood as an approach correcting wrong classifications of usual classifiers in a two-stage process: first an usual classification is performed, then the second classification integrating expert knowledge and out-image information is performed in order to improve the previous one (Král 2003).

A set of simple rules allowing integration of additional information and expert knowledge about ecological or socio economic considerations was established. An example of the rule, where ecological background of particular classes is used for their better differentiation give the classes Gm versus G1. A notion that cleared montane grasslands occur on Socotra Island at altitudes over 1000m above sea level was applied by means of DEM in the post-classification sorting.

An example of the rule where socio economic considerations are taken into account is shown on the improvement of the class U (Built-up land). As the out-image information the vector layer of fishing villages was employed. A simple assumption that major settlements are in the vicinity of either registered fishing villages or date palm plantations (DP) was used. The occurrence of DP was taken from the previous supervised classification since this class was classified by MLC classifier very well. The vicinity was defined in both cases by 500m buffer.

All classification process and subsequent post-classification rule-based sorting was performed by multiple reclassifications in ERDAS IMAGINE 8.31software.

3.5 *Accuracy assessment*

A simple accuracy assessment was carried out comparing the final land-cover map and reference evaluation fields. A confusion matrix was created and basic accuracy measures as overall accuracy, producer's and user's accuracy (Congalton 1991) were computed.

4. Results and discussion

The main output of this study is thus the first detailed land-cover map of Socotra Island distinguishing 19 terrestrial land-cover (mostly vegetation) classes (see figures 3 and 4). Until now, only one relevant vegetation map with 7 vegetation classes has existed (Miller and Morris 2001). This map is rather general and could serve only for overall information about spatial distribution of various vegetation types over the island whereas the new map gives sufficient information even on the local level. Distinguished classes of the resulting LC map are as follows:

0. Clouds.
1. Shadow of clouds.

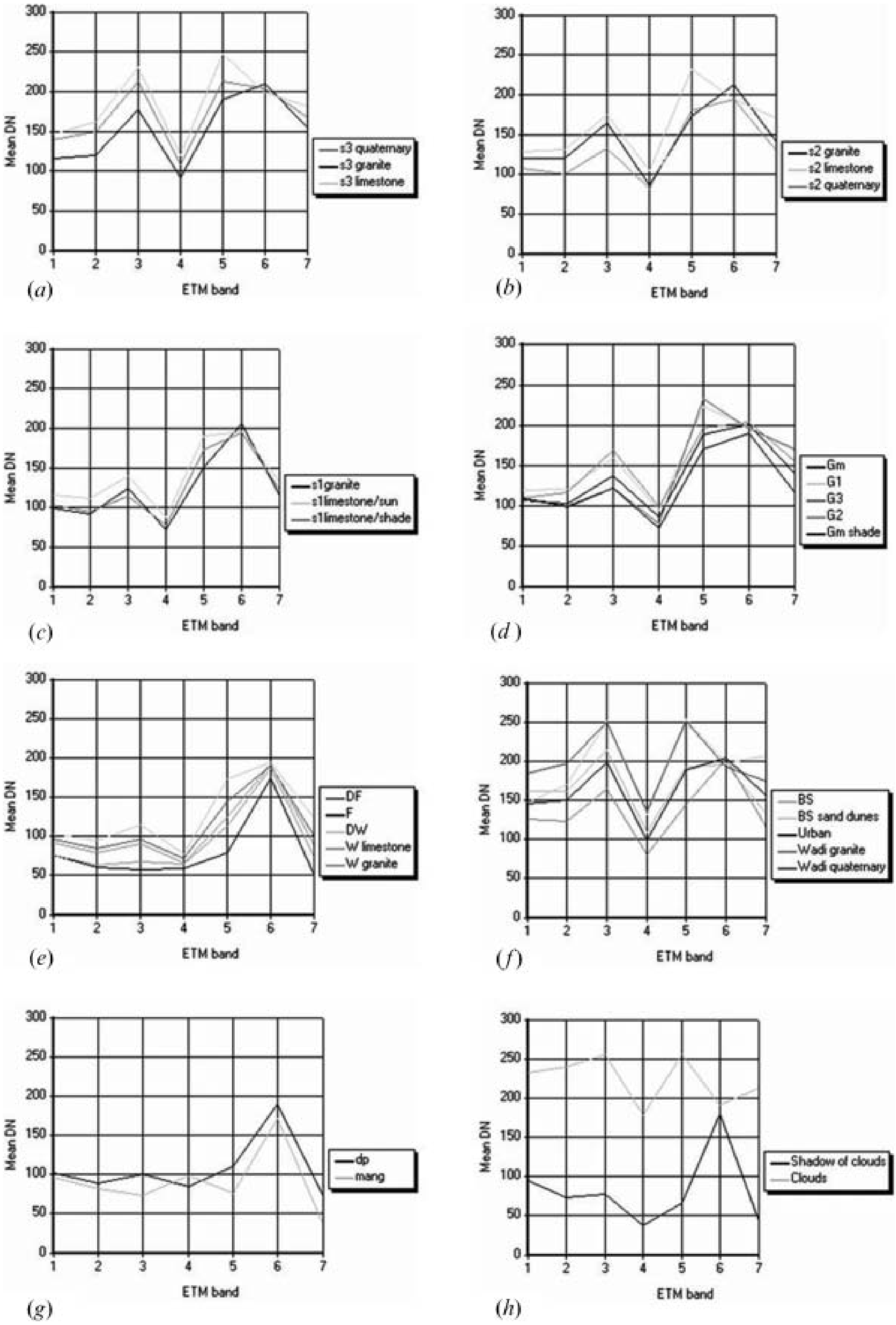

Figure 2. Spectral response curves of particular classes: (*a*) Dwarf shrubland, (*b*) Low shrubland, (*c*) High shrubland, (*d*) Grasslands, (*e*) Woodlands and Forests, (*f*) non-vegetation classes, (*g*) Date palm plantations and mangroves, (*h*) Clouds and their shadow.

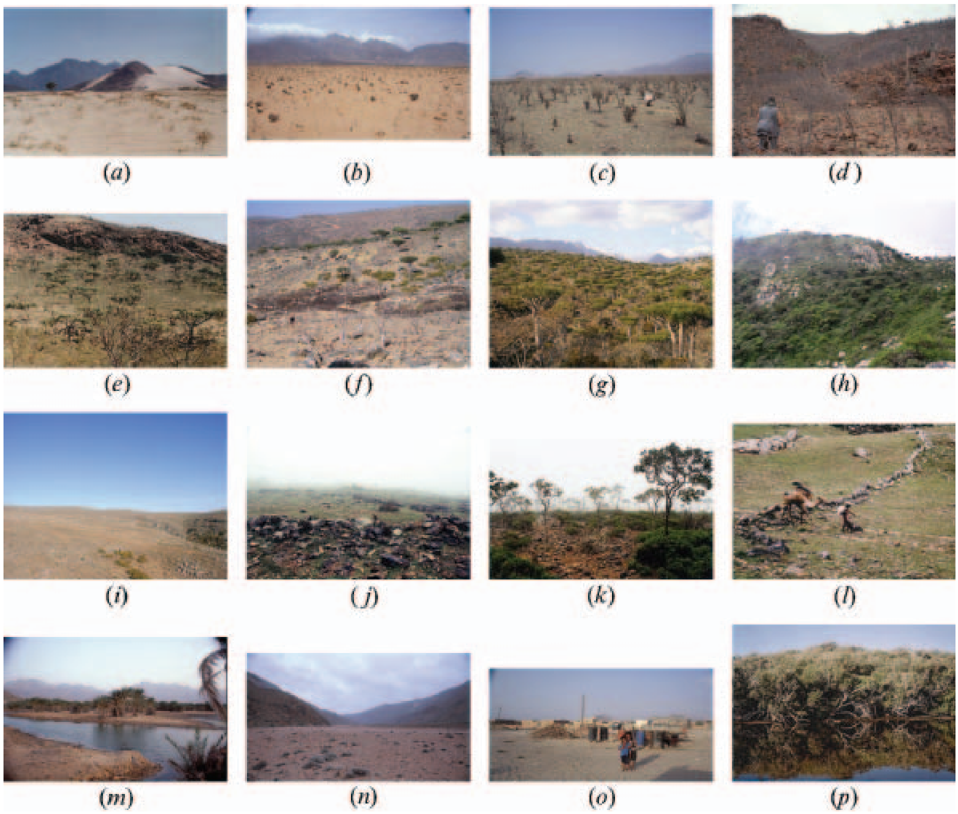

Figure 3. Ground photos of mapped land-cover classes (*a*) Bare soil, (*b*) Dwarf shrubland, (*c*) Low shrubland, (*d*) High shrubland, (*e*)Woodland, (*f*) Dracaena woodland, (*g*) Dracaena forest, (*h*) Forest, (*i*) Grassland on limestone plateau, (*j*) Grassland and sparse shrubland on limestone plateau, (*k*) Grassland/Submontane shrubland on limestone plateau, (*l*) Mountaine grassland, (*m*) Date palm plantations and Wetlands (Lagoons), (*n*) Wadi, (*o*) Built-up land, (*p*) Mangroves.

2. BS—Bare Soil (mostly sand and sand dunes). Mostly shifting, blowing sand dunes, almost no vegetation. Along the northern coast, at Ras Howlef *Acacia edgeworthii* forms a thin growth, while on the southern coast *Tamarix nilotica* predominates.
3. S3—Dwarf Shrubland (dominance of *Lycium socotranum*). The class merges all sparse dwarf shrublands of lowlands (their height usually do not exceed [0.5]1m), either natural—shaped by unfavourable climate and soil conditions (e.g. dry tough winds, high salinity, etc.), or man made biotopes, which are influenced by heavy overgrazing and wood collection and often arise by degradation of Low Croton-Jatropha shrubland.
4. S2—Low Shrubland (dominant *Croton socotranus* with *Jatropha unicostata*) occupies coastal and inland lowlands; it frequently encroaches on neighbouring low rolling hills and often remains dominant there; height up to 2(3) m; cover sparse-close.
5. S1—High Shrubland (*Jatropha unicostata, Croton sp., Adenium obesum, Euphorbia arbuscula*, etc.) Well-represented vegetation type with succulent species occupying steep foothills and slopes of central granitic mountains as well as foothills of most of the limestone plateaus. The height of the general

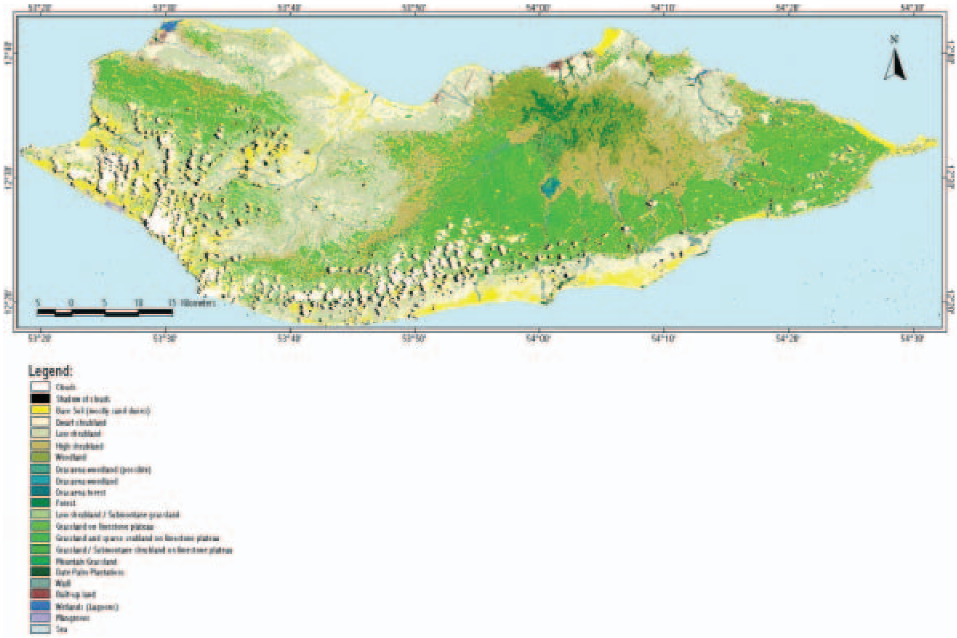

Figure 4. Final Land-cover map of Socotra Island.

level of the upper canopy usually range from 2 to 4(5)m, though at some exposed sites (especially on basement rocky slopes) can be considerable lower.

6. W—Woodland (*Boswellia sp., Commiphora ornifolia, Dracaena cinnabari*, etc.) develops on steep hill-sides and stony slopes. It is often a continuation of 'High shrubland' in higher parts of slopes. From the previous class it is distinguished by presence of tree species. The canopy closure of trees that are higher than 4(5)m should range from 5 to 30%.
7. DW1—possible occurrence of the Dracaena (*Dracaena cinnabari*) woodland. A typical vegetation type of Socotra that is characterised by evergreen endemic tree *Dracaena cinnabari.* In order to be mapped as this class, the canopy closure of 'Dragon's blood trees' in the formation should range between 5 and 30%. Nevertheless, in some cases, it is possible that areas with lower canopy closure were included.
8. DW2—Dracaena Woodland (*Dracaena cinnabari*). As previous class, however at sites where the condition of canopy closure (5–30%) is assuredly fulfilled.
9. DF—Dracaena Forest (*Dracaena cinnabari*). Analogical to two previous classes, distinguished only by higher canopy closure of the determinant tree *Dracaena cinnabari* (over 30%). It is restricted to Firmihin locality, since no other stands on Socotra reach sufficient density. This vegetation type is unique to Socotra and as such is extremly important.
10. F—Forest (mostly montane forest with dominance of *Euclea balfourii, Euphorbia socotrana, Dracaena cinnabari, Pittosporum viridiflorum, etc.*). The tree layer higher than [4]5m has canopy closure 30% at least. The class includes also patches of Frankincense forests of lower altitudes formed by *Boswellia* spp. and *Commiphora* spp.
11. S2/G—Transition between S2 and G on low undulating hills (often with *Croton socotranus* and *Commiphora socotrana*)

12. G1—limestone plateau with Grassland. Well-represented landcover class, comprising open grass and woody based herb communities of the limestone plateaus with scarce individuals of dwarf shrubs (their height usually do not exceed 0.5m). It occupies especially flat summits of lower plateaus.
13. G2—limestone plateau with Grassland and shrubs (e.g. *Croton socotranus, Lycium sokotranum* and *Solanum incanum*), transition between G1 and G3.
14. G3—limestone plateau with Grassland/Submontane shrubland confined to summits of higher limestone plateaus. The woody vegetation is dominated by *Buxanthus pedicellatus* and *Croton socotranus*; emergent trees of *Dracaena cinnabari* may occur.
15. Gm—Mountain Grassland usually without shrubs; often presence of granodiorit rocks and stones; confined to gentle slopes of the Haggeher Mts., generally above the height of 1000m.
16. DP—Date Palm Plantations (*Phoenix dactylifera*); present over small areas along the most of the wadis and coastal lagoons.
17. Wadi—wide distinct riverbeds of sporadic watercourses. The surface of the streams is formed by diverse boulders, debris and gravel usually without any vegetation cover.
18. U—built-up area ('Urban'). The class more or less restricted to two major sites on the northern coast: Haddiboh (and surrounding villages) in central part and Qalansiyah in the northwest. The Mouri Airport and some surrounding villages were recognised as well.
19. Wt—Wetland (Lagoons) occur particularly on the northern coast mainly in estuaries of north running wadis as small fresh or brackish lagoons separated from the sea by spits and bars.
20. Mang—Mangroves (*Avicennia marina*); local narrow belts at three points along the coasts of Socotra.
21. Sea.

The confusion matrix gives basic information about the reliability of the new land-cover map (see table 1). Overall accuracy of the map is more than 80%. User's and producer's accuracy of particular classes is listed in the table as well. Moreover, the table indicates a Statistic index. According to Gay (2001) it is a ratio between the total area of a certain class according to the result of the classification and a total area of this class according to the reference data within evaluation fields. It provides information whether the class is overestimated or underestimated in the classification product. In ideal case, the value of statistic index is 100%.

Evaluating the correctness of mapping of particular classes by means of the above mentioned accuracy indicators we can find some indispensable misclassifications. An example gives the confusion between classes S2 (Low shrubland) and S3 (Dwarf shrubland) where especially sparse S2 is in places misclassified as the class S3. Consequently the area of S3 is overestimated according to the Statistic index (and S2 underestimated). Similarly, dense 'High shrubland' (S1) is sometimes classified as 'Woodland' (W) and consequently the area of the class W is overestimated (see table 1). Since in both cases, it is often the question of continuous transitions between those classes the confusion is to a certain extent natural and inevitable.

Another remarkable confusion is between classes W, DW1 (Potential Dracaena Woodland) and DW2 (Dracaena Woodland). Nevertheless, these three classes belong to the same general group of biotopes types—Woodlands. Moreover, low values of accuracy indicators for the class DW2 are probably caused by the

Table 1. Confusion matrix for the final land-cover map.

Classification data [pixel count]		Refference data [pixel count]																				
	Class	BS	S3	S2	S1	W	DW1	DW2	DF	F	S2/G	G1	G2	G3	Gm	DP	Wadi	U	Wt	Mang.	Total	User's acc.	Stat. in.
	BS	3259	69	42	1	0	0	0	0	0	0	1	0	0	0	0	15	0	0	1	3388	*96.2%*	96.7%
	S3	195	3116	1489	6	0	0	0	0	0	0	118	0	0	0	13	128	27	4	0	5096	*61.1%*	123.7%
	S2	16	891	10 668	152	2	0	0	0	0	10	121	0	0	3	6	151	4	2	0	12 026	*88.7%*	91.3%
	S1	1	2	830	8210	188	101	4	0	2	9	272	31	2	44	11	107	0	0	0	9814	*83.7%*	97.6%
	W	0	0	1	668	22 66	123	53	0	39	0	69	10	16	280	8	3	0	0	0	3536	*64.1%*	132.3%
	DW1	0	0	0	200	45	383	32	0	0	0	7	1	1	3	3	0	0	0	0	675	*56.7%*	107.8%
	DW2	0	0	0	0	0	0	92	15	0	0	2	5	0	0	0	0	0	0	0	114	*80.7%*	49.8%
	DF	0	0	0	0	0	0	12	177	0	0	0	0	0	0	0	0	0	0	0	189	*93.7%*	98.4%
	F	0	0	0	1	149	0	0	0	1282	0	0	0	0	0	0	0	0	0	0	1432	*89.5%*	108.2%
	S2/G	0	0	15	9	0	0	0	0	0	581	232	0	0	0	0	1	0	0	1	839	*69.2%*	136.4%
	G1	0	14	44	513	5	3	28	0	0	15	2095	180	125	341	4	5	0	0	0	3372	*62.1%*	111.9%
	G2	0	0	0	0	0	0	0	0	0	0	0	235	0	0	0	0	0	0	0	235	*100.0%*	47.3%
	G3	0	0	0	272	3	4	6	0	0	0	96	35	395	124	0	3	0	0	0	938	*42.1%*	174.0%
	Gm	0	0	0	0	0	0	0	0	0	0	0	0	0	993	0	0	0	0	0	993	*100.0%*	55.4%
	DP	0	4	12	15	15	12	2	0	1	0	0	0	0	5	534	23	0	10	0	633	*84.4%*	106.4%
	Wadi	7	6	27	0	0	0	0	0	0	0	0	0	0	0	10	3011	0	0	0	3061	*98.4%*	88.7%
	U	25	18	41	4	0	0	0	0	0	0	0	0	0	0	3	5	460	0	0	556	*82.7%*	113.2%
	Wt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1242	0	1245	*99.8%*	99.0%
	Mang.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	162	162	*100.0%*	98.8%
	Total	3503	4120	13 169	10 051	2673	626	229	192	1324	615	3013	497	539	1793	595	3452	491	1258	164	48 304		
	Prod.ac.	*93.0%*	*75.6%*	*81.0%*	*81.7%*	*84.8%*	*61.2%*	*40.2%*	*92.2%*	*96.8%*	*94.5%*	*69.5%*	*47.3%*	*73.3%*	*55.4%*	*89.7%*	*87.2%*	*93.7%*	*98.7%*	*98.8%*	Overall accuracy 81,1%		

insufficient extent of reference (evaluation) fields. Therefore, the results can be still considered as fair.

The last indispensable occurrence of misclassifications is between classes S2/G and Gm (marked out by bold box in table 1). Again, it is the question of classes distinguished on the level of BT within one GBT—Grasslands. On the example of the class Gm which was mapped by the help of post-classification sorting it can be observed how the integration of additional knowledge acts in the classification process: It particularly improves user's accuracy (removes commission errors) within a class which can unfortunately lead to the underestimation of the class extent (see table 1).

Estimates of the area and degree of coverage of particular land-cover classes within Socotra Island are listed in table 2. Clouds and their shadows over the island (classes 0 and 1) were included in the calculation (clouds above the sea were excluded). Therefore, values of the absolute area and especially of the degree of coverage of particular classes are little biased. Moreover the total area of the class Bare Soil is probably overestimated since in the most clouded part of the island (the south-west part) pixels affected by cloud edges were classified mostly just as the Bare Soil. This effect is not revealed by the statistic index (table 1) due to the lack of reference data from this inaccessible part of the island.

5. Conclusions

Experience and the first results acquired in the process of dealing with the land-cover map of Socotra Island show that incorporation of data and techniques of RS in the mapping process brings a significant improvement of monitoring procedures in terms of data accuracy, cost effectiveness, spatial differentiation and timeliness. A detailed LC map of the island could not be created in comparable quality, costs and time limit by the terrain survey only. Moreover, the procedure combining supervised maximum-likelihood classification and rule-based post-classification sorting provides results of sufficient accuracy and subject resolution (overall accuracy more than 80% mapping 19 terrestrial LC classes) while maximizing user's accuracy of the final map product.

Consecutive simple GIS analysis enables estimates of highly valuable information as absolute global area and relative degree of coverage of particular classes (biotopes) over the island. It consequently allows for example estimates of the

Table 2. Area and degree of coverage of particular land-cover classes on Socotra Island.

No.	Land-cover Class	Pixel count	AREA (ha)	Degree of coverage %
0	Clouds	181 045	16 758	4.6%
1	Shadow of clouds	84 110	7 785	2.2%
2	Bare Soil (BS)	271 340	25 116	7.0%
3	Dwarf Shrubland (S3)	500 534	46 331	12.8%
4	Low Shrubland (S2)	892 903	82 651	23.3%
5	High Shrubland (S1)	621 461	57 525	15.9%
6	Woodland (W)	222 040	20 553	5.7%
7	Potential DW (DW1)	35 024	3 241	0.9%
8	Dracaena Woodland (DW2)	2 028	187	0.1%
9	Dracaena Forest (DF)	2 465	228	0.1%
10	Forest (F)	34 265	3 171	0.9%
11	Transition S2/G	212 462	19 666	5.5%
12	Grassland on limestone plateau (G1)	549 216	50 838	14.1%
13	Grassland with sparse shrubs (G2)	102 303	9 469	2.6%
14	Grassland/Submont. shrubland (G3)	75 978	7 032	2.0%
15	Montane Grassland (Gm)	10 485	970	0.3%
16	Date Palm Plantations (DP)	17 504	1 620	0.5%
17	Wadi	45 867	4 245	1.2%
18	Built-up Land (U)	4 833	447	0.1%
19	Wetland (Wt)	4 277	395	0.1%
20	Mangroves (Mg)	1 947	180	0.1%
	Island TOTAL	3 872 086	358 408	100%

current and potential occurrence (and abundance) of rare species—e.g. unique biotopes of endemic Dragon blood tree (*Dracaena cinnabari*): Dracaena Forest (DF), Dracaena Woodland (DW2) and Potential Dracaena Woodland (DW1), which are essential for their protection and management.

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