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Mapping of ecosystem services flow in Mida Creek, Kenya

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A B S T R A C T

The concept of ecosystem services (ES) and its application in natural resources management decision making is a new conservation paradigm. A better understanding of ES in resource-rich developing countries can contribute to poverty alleviation and sustainable development, while at the same time conserving natural resources. This study assessed the flow of ES in Mida Creek, a marine reserve in Kenya, with the aim of characterizing land use/land cover (LULC) classes, spatially mapping distribution of ES, identifying important ES, and establishing the opinions of experts on ES flow. A qualitative and quantitative assessment was carried out coupling expert scores and LULC maps in a matrix structure. A participatory approach was used to engage and raise awareness with the community groups who actively participate in conservation activities in the creek, together with researchers/academics/managers who also are involved with the management of the reserve. The study was carried out between July and October 2015 and a total of 65 participants were involved. Datasets were collected using questionnaires in which ecosystem service flow was scored based on expert estimates per LULC class against the selected ES. Data were assessed using statistical and spatial analysis techniques. Results for the flow of provisioning services showed that, while palm trees were the main source of firewood (68%), other vegetation types were also an important source for wood products, including charcoal (46%), construction poles (54%) and fishing gear (68%). There was also a high flow of provisioning services (sea food and bait organisms) from water bodies (82%) and mangroves (80%). Flow for regulating services was mainly from mangroves, and for cultural services from beaches, mangroves and water bodies. Saline bare areas and sand flats scored least for all the ES. There were statistically significant differences in the scoring of the LULC against the different categories of provisioning, regulating and cultural services between the local communities and the other stakeholders. The method shows both the location of the resources utilized by the communities and, also, facilitates communication between these communities and the decision makers, thereby providing an example of a management strategy at the local scale for other coastal regions of Kenya and elsewhere.

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1. Introduction

Marine and coastal ecosystems provide an extensive range of services to human society including supporting, regulating, cultural and provisioning services (UNEP-WCMC, 2011). However, many of these ecosystems are under increasing threat from human-related exploitation, both for direct (e.g. fishing) and indirect (e.g. tourism) consumption. Increasing societal demand for marine resources has led to substantial alterations in the flow of ecosystem services (ES) and even loss of services e.g. flood protection and water quality (Small et al., 2000; Small and Nicholls, 2003). The Millennium

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Ecosystem Assessment (M.E.A, 2005a, b), a synthesis of scientific knowledge about global ecosystems and their capacity to support human well-being, showed that human use of marine and coastal ecosystems is expanding, commensurate with the growth of coastal human population and expansion of consumption. With many competing uses of marine and coastal ecosystems and their services, there is a need to formulate and improve policies that will catalyse management efforts to reverse their continued decline.

Formulation of policy and implementation of management decisions to reduce, or even reverse ecosystem decline, will require a consideration of ES. Recently, studies have suggested that incorporating ES information into environmental policies and management can lead to environmental decisions that secure a broader set of desired future outcomes (Daily et al., 2009; Turner and Daily, 2008; Arkema et al., 2015; Schaefer et al., 2015). Managing natural capital from an ES perspective is useful in establishing priorities for the management of essential functions of ecosystems (Balmford et al., 2002), thus enabling natural resource managers to focus on the areas and habitats that deliver the greatest amount and/or the highest value of ES (Kremen, 2005). Alternatively, priorities can also be based on the most critical threats to the delivery of ES from the most valuable areas (Leslie and McLeod, 2007). Thus, scientific understanding of ES will provide basic information that will enable resource managers to take adaptive management measures; thereby, ensuring that the supply and capacity of an ecosystem to provide services is not degraded (Leslie and McLeod, 2007; Palomo et al., 2013; Arkema et al., 2015).

Managing natural capital to maintain ecosystem structure and function requires evidence to demonstrate how the incorporation of natural capital and ES into decision making can lead to better outcomes for improving human well-being (Guerry et al., 2015). This evidence also requires a multidisciplinary approach that can integrate the data on the physical, economic and social aspects of ecosystems. Policy makers and resource managers have begun to apply the ES perspective into marine and coastal policy and management, although it is not yet a usual practice. Most assessments and mapping of ES are still focused on large scales, hindering the use of such assessments for decision making at the national, and sub-national scale (M.E.A, 2005a, b; Turner and Daily, 2008). Therefore, there is a need to increase assessments and mapping of ES at smaller geographical scales, consistent with capturing all the relevant effects of the biophysical and social processes (Lovell et al., 2002; Perrings et al., 2011) necessary for decision makers to address impacts on biodiversity and ecosystem change at the local level.

There are several components of ES delivery that can be assessed including capacity, demand, ecological pressure and flow (Villamagna et al., 2013; Burkhard et al., 2014). Flow is defined by Burkhard et al. (2014) as a set of ES currently consumed or used in a particular area over a given period of time. In Kenya, like in other African countries, most of the communities' livelihoods revolve around natural resources (Egoh et al., 2012). Therefore, there is need to understand how people interact with the environment in order to identify sources of problems (Stedman-Edwards, 1997). The ES approach is one way to promote conservation of marine resources because it focuses on the social, ecological and economic aspects of a system (M.E.A, 2005a, b). Mapping of flow enables the evaluation of ES sustainability using different scenarios. It also gives information on the current and future biophysical capacity of an area to produce ES (Villamagna et al., 2013). Understanding of the flow of ES and their spatial distribution should support adaptive management of Marine Protected Areas (MPA) in Kenya. Managers can then take adaptive measures to ensure that supply and capacity of the ecosystem to provide services is not degraded (Burkhard et al., 2012; Palomo et al., 2013).

In Kenya, there are two types of MPA. The first category comprises Marine National Parks (MNP), where there is total protection from any type of direct consumption, although indirect activities such as tourism can take place for a fee (Tuda et al., 2014) and, the second is Marine National Reserves (MNR), which allows traditional harvesting of resources, as well as research and tourism (Tuda and Omar, 2012). Extending the work of Kirui et al. (2013), who focused on mangrove land cover changes at a large scale along the Kenya coast, this study has characterized land use/land cover classes of a mangrove area at the local scale of the Mida Creek MNR. Despite being a resource-rich area, poverty levels in the study area and its surroundings is still high (Government of Kenya, 2009), and degradation of natural resources is on the rise through illegal activities that have led to the loss of biodiversity (Muthiga et al., 2000; Muthiga, 2009). Through this study, a matrix approach has been used to develop spatial maps of ES flow, to identify important ES, and to establish opinions of experts on ES flow (Burkhard et al., 2009; Jacobs et al., 2015). The findings of this study on the assessment of ES flow using mapping techniques will inform better management strategies for the Kenyan coast, as well a raising awareness and educating the community about ES. The results will also add to the literature on mapping of ES in developing countries at local scales.

2. Study area and methods

2.1. Description of Mida Creek

Mida Creek is part of the Watamu Marine National Reserve in Kenya. It covers an area of 31.6 km^2 (Dahdouh-Guebas et al., 2000), and is situated 100 km North of Mombasa in Kilifi County (Fig. 1). Watamu Marine reserve is part of the Watamu-Malindi Marine Reserve complex (Fig. 1), which in 1979 was recognized and designated as a Biosphere Reserve (Kairo et al., 2002). The study area is under the jurisdiction of the Kenya Wildlife Service (KWS) who take planning and management decisions (Weru, 2001), and the Kenya Forest Service (KFS) who are responsible for the mangrove forest reserve. Mangrove forest is the dominant habitat in the Creek, occupying 1746 ha, and supporting 7 of the 9 mangrove species found in Kenya (Kairo, 2001). The extensive sand flats in the area also form important habitats for shorebirds (Kairo, 2001), which has led to its global recognition as an Important Bird Area. It is an important Social Ecological System (SES) for the local community who can access the reserve for fishing, tourism and conservation activities. However, to access and cut mangroves, community members require licenses from KFS while fishing licences are obtained from the Fisheries department. The different mandates have sometimes led to confusion and even conflict among resource users; for example, disagreement between sport and artisanal fishers over the collection of 'bait' organisms from the reserve by sport fishers (Weru, 2001). The other issues facing the area are overexploitation of fish stocks, use of destructive fishing methods and poaching. These various conflicts indicate a need for a renewed integrated natural resource management strategy that will provide a management framework for the sustainable use of these natural resources (Vrebos et al., 2015).

2.2. Methods

This study tested the land use/land cover (LULC) matrix approach developed by Burkhard et al. (2009). Local knowledge and expert views were integrated with LULC data in a qualitative and quantitative assessment. The methods that were used in the study included: (1) selection of ES using literature review and expert knowledge; (2) use of a matrix approach for scoring flow of

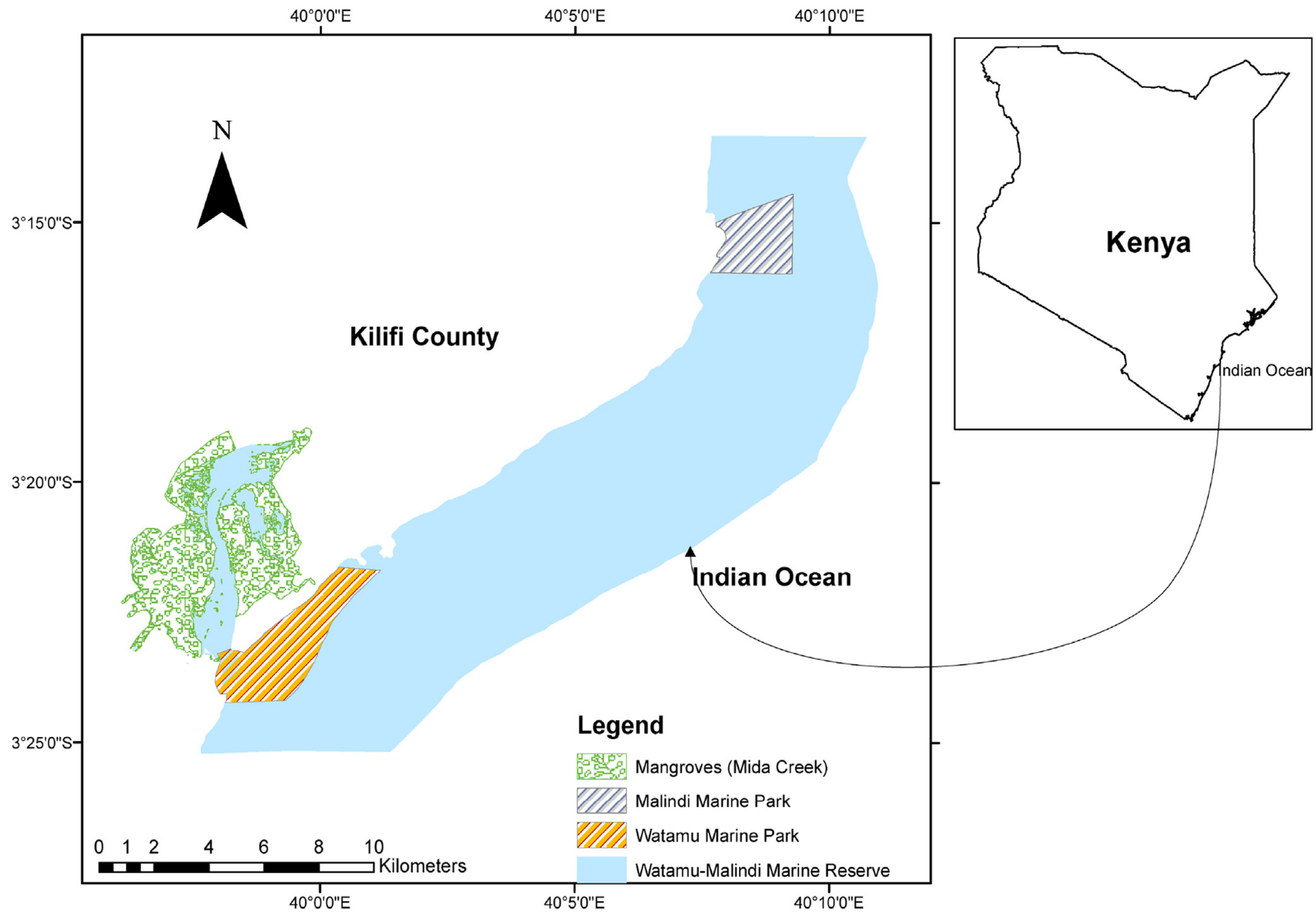

Fig. 1. Location of the study area (Mida Creek) in the Watamu-Malindi Reserve complex. (Adapted from Protected Planet, 2016).

the ecosystem services by landscape type (Burkhard et al., 2009, 2014; Jacobs et al., 2015); and (3) use of remote sensing and ArcGIS to visualize the spatial distribution of the landscapes and flow of ES.

2.2.1. Selection of ES

The ES selected for mapping were identified using the criteria outlined in the Millennium Assessment report of 2005, as well as through interviews with key stakeholders. The stakeholders included the community representatives and the park and reserve managers; the majority of the community representatives belonged to community based organizations from the villages around Mida Creek. The ES categories were defined with the help of the Mida Creek conservation group leaders to reflect the different components of the services utilized by the community living around Mida Creek and modified following definitions by Kandziora et al. (2013) (Table 1). Nineteen ES were surveyed, although only sixteen of these were assessed including: provisioning (firewood, charcoal, construction poles, fishing gear, honey, medicine, fisheries, and wild foods); regulating (erosion protection, carbon sequestration, flood protection, nutrient regulation); and cultural (education and research, cultural shrines, tourism and recreation, and intrinsic values). It is important to note that supporting services were not used in the analysis of this study to avoid double counting (see detailed justification in Fisher et al., 2009).

2.2.2. Matrix table scoring and mapping of ES flow

A participatory approach, through a series of four workshops was used to collect data from July to October 2015. To assess the ES, scoring tables for ES flow were designed using LULC classes for Mida Creek for the rows and the selected ES for the columns (Jacobs et al., 2015). Three of the workshops were held with community based organizations, covering the entire Mida Creek. The first workshop was held in Dabaso Mida Board Walk with 18 participants from the villages of Dongo Kundu, Turtle Bay, Temple Point, Dabaso village, Sita and Chafisi villages. The second workshop was held in Mida Bandas with 16 participants from the villages of Mida Majaoni, Mida Msikitini, and Magangani. The third workshop was held in Uyombo with 14 participants from Uyombo sub-location. While the last workshop was held in Pwani University with 17 participants from research and academia, government agencies, non-governmental organizations (NGO's), and senior managers from the marine park and reserve. A total of 65 participants took part in the survey. Selection of the participants was done bearing in mind the multiplicity of users in Mida Creek (Van Oudenhoven et al., 2012; García-Nieto et al., 2015), and was sufficiently diverse to represent most of the key stakeholders involved in carrying out research, and in the conservation of the Creek. Several issues were discussed during the meetings ranging from the topic of ES, defining ES, the potential of Mida Creek to provide these services, to the state of management of the reserve and the different organizations involved. Participants were taken through an introductory session in which they refreshed their familiarity with the ecosystem types in Mida Creek, defined what ES is and discussed the ES classification using the Millennium Ecosystem Assessment (M.E.A) framework. This was then followed by scoring the matrix table (showing the selected ES against the Land

Table 1
Selected ES in Mida Creek with definitions of the categories (modified from Kandziora et al., 2013).

Ecosystem services	Definitions of categories
Provisioning services	
Firewood	Fuelwood used in cooking harvested from Mida Creek
Charcoal	Charcoal obtained from burning trees cut from Mida Creek
Construction poles	Building material harnessed from Mida Creek
Fishing gear	Paddling gear, traps, wood materials for making canoes
Honey	Honey harvested from bee hives set up in the mangrove forest and on other non-mangrove vegetation
Medicinal plants	Medicine harnessed from the Mida Creek for example from mangrove and other vegetation.
Fisheries	Seafood and bait supplies harvested from the creek and aquaculture.
Wild food	Collection of wild food from the mangrove forest and other vegetation
Regulating services	
Erosion protection	Capacity to mitigate soil and sediment erosion
Carbon sequestration	Storage of greenhouse gases
Flood protection	Mitigation from rainfall and floods, and events like tsunamis
Nutrient regulation	Capacity to buffer excess nutrient loads controlling pollution
Cultural Services	
Education and Research	*Education*- schools, colleges and university visits to Mida Creek area.
	Research- research institutes, colleges, universities government bodies visiting for research.
Cultural shrines	'Kayas' religious shrines, mosques and churches
Recreation and Tourism	*Recreation*- activities like canoe riding, bird watching
	Tourism- the number of visitors currently coming to the creek.
Intrinsic values	Personal desire to have the habitats exist irrespective of their importance.

cover/Land use) on ES flow. Participants were encouraged to make the scores individually. Scoring was: 0 for no flow; 1, very low flow; 2, for low flow; 3, for medium flow; 4, for high flow; and 5, for very high flow. This was then followed by a debriefing session of questions which required the participants to give reasons why they made their choices. Data from the matrix scores were then compiled to process spatially explicit ES maps using ArcMap (ArcGIS 10.3). The colour scheme used in the matrix table and maps were adopted from (Burkhard et al., 2009), where 0/rosy = no flow; 1/grey green = very low flow; 2/light green = low flow; 3/yellow green = medium flow; 4/blue green = high flow; 5/dark green = very high flow.

2.2.3. Land cover/land use map design

A LULC map comprising of both natural and human modified systems (Metzger et al., 2006; Maes et al., 2012) was processed using Remote Sensing ENVI software and ArcMap (ArcGIS 10.3) platform. SPOT 4 and 5 images for the month of March 2015 were used to develop the maps. LULC classes were validated through a ground truthing exercise using GPS, NLCD 2006 system of Land Cover Class Definitions (Fry et al., 2011) and other sources like Kairo (2001). Class divisions were mapped for eight categories: mangroves; other vegetation types (casuarina, neem, cashewnuts); palm trees, settlements, beaches; water body areas (channels and creeks); sand flats; and saline bare areas.

2.3. Data analysis

There were two types of data that were collected: 1) experts (community practitioners and researchers/academics/managers) views on the flow of the ecosystem services from the various landscape types in Watamu Marine Reserve (Mida Creek); and 2) the spatial extent of the landscapes and the distribution of the ecosystem services. The data on the views of the community practitioners and researchers/academics/managers was analysed using various statistical applications for the descriptive analysis (using SPSS version 20). Measures of the means of the various ecosystem services across the landscapes and land uses identified scores within a scale the 0 to 5 to denote the level of flow for each service. Measures of proportions were also used to assess the percentage of participants who favoured high flows of particular ecosystem services across the landscape (Brown, 2011). Finally, inferential analysis was used to compare the levels of understanding of the flows of the ecosystem services across landscapes by the community members and researchers/academics/managers. A one-way multivariate analysis of variance (MANOVA) was the most suitable statistical tool to carry out this analysis, since there was only one independent variable and several interval dependent variables. A post-hoc test was conducted to determine which landscape types differed from each other in the provision of the services.

3. Results

3.1. Land use/land cover classes for Mida Creek

Results of mapping of the Mida Creek area for both the natural and human altered habitats showed that mangrove habitats are the most dominant land cover in this Creek (17.429 km^2), followed by areas occupied with water bodies (14.073 km^2) (Fig. 2).

Table 1 shows the selected ES categories that are relevant to Mida Creek and the definitions of each of the categories used in this study.

3.2. Quantification and mapping of ecosystem service flow

3.2.1. Matrix scores

Results of the expert scores are presented in the (Table 2) below. The scores revealed that different LULC mapped in Fig. 2 provide different services to the community.

3.2.1.1. Flow of provisioning ecosystem services. Palm trees, other vegetation types and mangroves provided most of the firewood in Mida Creek (Table 2). Results show that while palm trees were the mains source of firewood (68%), there was flow of ES from other vegetation (55%) and mangroves (44%). Thus, palm trees are the most important source of firewood, supplying more than two thirds of the ES. The main source of charcoal was other vegetation (46%), mangroves (18%), palm trees (13%), and settlements (10%). For construction poles, there was medium flow from other vegetation (54%) and mangroves (50%). However, there was no flow from saline bare areas (93%), water body area (91%) sand flats (88%), and beaches (84%). In Mida Creek, the high flow of honey was from mangroves at (72%), and medium flow from other vegetation types at (58%). While other vegetation types were the main source of

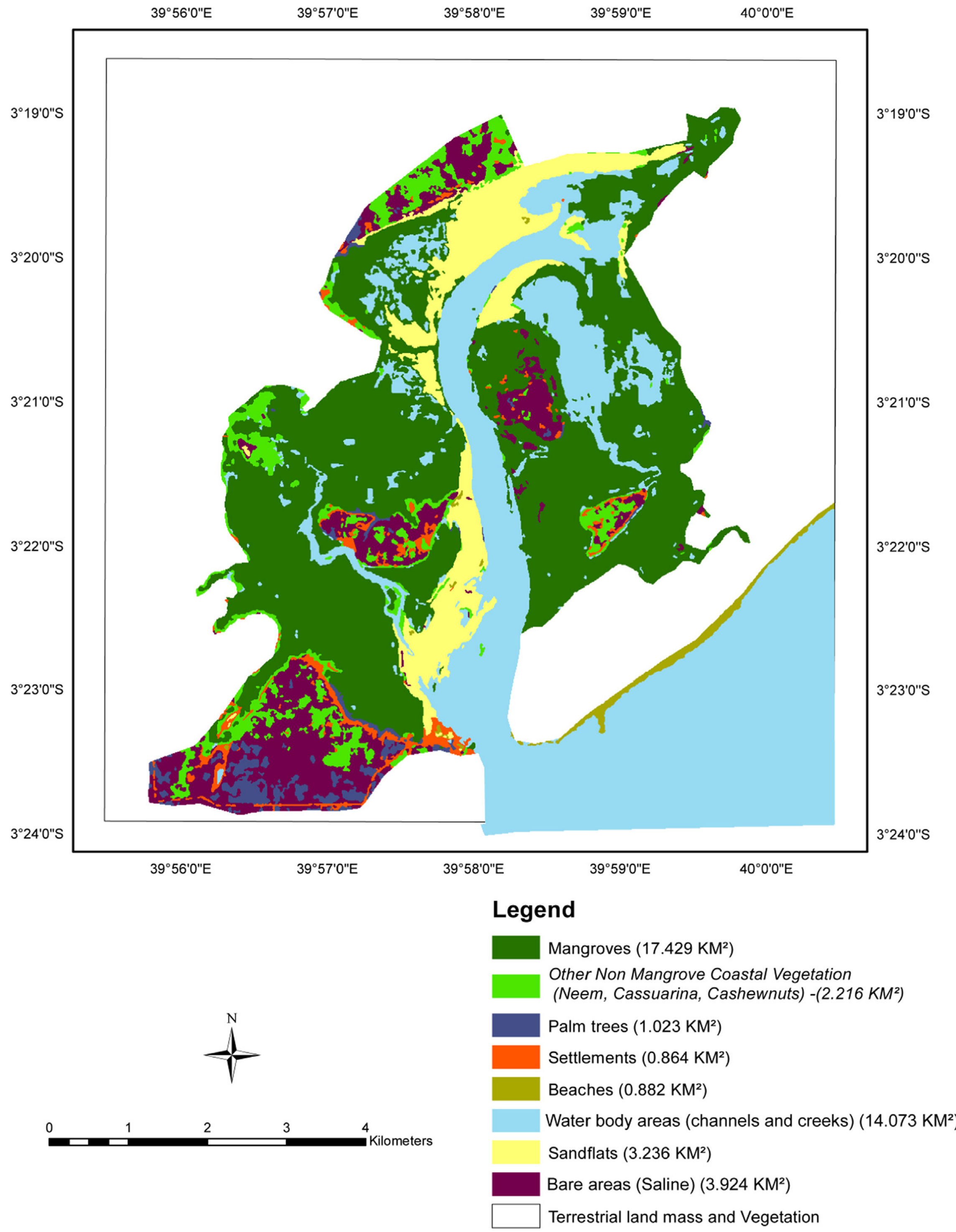

Fig. 2. Map of LULC classes for selected ecosystems in Mida Creek with a legend for the categories (adapted from Kairo, 2001).

herbal medicines (68%), there was also low flow from mangroves (20%). Other vegetation types are the main source of wild foods registering a medium flow of 11%. Finally, for fisheries, high flow was from water body areas (82%) and mangroves (80%), and low flow was from beaches (12%) and settlements (8%).

Data analysis was conducted to assess if perception and understanding of the flow of ecosystem services was different based on the profile of the participants. Taking the interval variables for the ES, a one-way MANOVA was conducted for provisioning services. The results are presented in Table 3 below in which the reported results include the mean values of the scores ranging from 0 to 5, where 0 denotes no flow, 1 = very low flow, 2 = low flow, 3 = medium flow, 4 = high flow, 5 = very high flow, the significance values i.e. p-values below 0.05, the F-values and the η^2.

Table 2
Matrix illustrating flow of ES in Mida Creek. Mean values from expert estimations: 0, rosy = no flow; 1, grey green = very low flow; 2, light green = low flow; 3, yellow green = medium flow; 4, blue green = high flow; 5, dark green = very high flow.

	Provisioning services	*Firewood*	*Charcoal*	*Construction poles*	*Fishing gear*	*Honey*	*Medicine*	*Fisheries*	*Wildfoods*		**Regulating services**	*Erosion protection*	*Carbon sequestration*	*Flood protection*	*Nutrient regulation*		**Cultural services**	*Education &Research*	*Cultural shrines*	*Recreation & Tourism*	*Intrinsic values*
Mangrove		3	2	3	3	4	2	4	1			5	4	4	4			4	1	4	3
Other vegetation (Casuarina, Neem, Cashewnuts)		3	3	3	4	3	4	1	3			3	3	3	3			3	3	3	3
Palm trees		4	1	3	1	1	2	0	1			2	2	2	2			2	1	2	3
Settlements		2	1	1	1	2	1	1	1			2	1	1	1			2	2	3	3
Beaches		1	0	0	0	0	1	1	0			1	1	1	1			2	1	4	3
Water (Channels/Creeks)		1	0	0	0	0	0	4	0			1	2	1	2			3	1	3	3
Sand flats		0	0	0	0	0	0	0	0			1	0	1	1			1	0	2	3
Bare areas (saline)		0	0	0	0	0	0	0	0			1	0	0	1			1	0	1	1

Table 3
Summary of the statistically significant one way MANOVA-test for the assessment of provisioning ES flows from selected LULC with high scores based on participants' profiles.

Provisioning services	LULC with high score	Mean score of flow by community practitioners	Mean score of flow by researchers/academics/managers	Aggregate mean scores of flows	F-Values	P-Values	η^2
Firewood	Mangroves	2.7	4.2	3.2	(3,63) = 8.52	<0.0005	0.29
	Other vegetation types	3.6	2.8	3.4			
	Palm trees	4.2	3.1	3.9			
Charcoal	Mangroves	1.4	3.3	1.9	(2,64) = 14.55	<0.0005	0.31
	Other vegetation types	3.0	2.7	2.9			
Building Poles	Mangroves	3.1	4.2	3.4	(2, 62) = 10.46	<0.0005	0.25
	Other vegetation types	3.6	2.9	3.5			
Honey	Mangroves	4.4	3.1	4.1	(2, 62) = 9.49	<0.0005	0.23
	Other vegetation types	3.7	2.6	3.4			
Herbal medicine	Mangroves	2.3	2.6	2.4	(3,61) = 4.00	=0.011	0.16
	Other vegetation types	4.0	3.0	3.7			
	Settlements	1.8	0.5	1.5			
Fisheries	Mangroves	4.3	3.8	4.1	(2,62) = 5.35	=0.007	0.15
	Open water body areas	4.4	3.1	4.1			

η^2 – Partial eta-squared, n = 65.

3.2.1.2. Flow of regulating ecosystem services. Mangroves were shown to be important for the provision of all the regulating services assessed compared with other LULC types (Table 4). High flow of erosion protection was recorded from mangroves (92%), medium flow from other vegetation (62%), very low flow from water body areas and saline bare areas. Mangroves were also viewed to have an important role in carbon sequestration (81%), compared with other LULC types i.e. vegetation types (37%). However, in contrast, no flow of carbon sequestration was recorded for sand flats and saline bare areas.

Mangroves were important for flood protection (80%) followed by other vegetation (58%) while no flow of this service from saline bare areas (74%). Results for regulating services also show that mangroves (73%) played an important role in nutrient regulation, followed by other vegetation (45%). A one way MANOVA was also conducted to test if views and understanding on flow of regulatory services differed according to the profile of participants (i.e. community practitioners and researchers/academics/managers). Results showed that only soil erosion ES was statistically significant, with the community practitioners giving higher scores compared to the researchers/academics/managers for the mangroves, other vegetation and settlements (Table 4).

3.2.1.3. Flow of cultural ecosystem services. Results show that while mangroves were preferred for education and research, water body areas and other vegetation also recorded medium flow for each. Saline bare areas and sand flats recorded low flow at 38% and 29% respectively. For cultural shrines, medium flow was from other vegetation, while from settlements there was low flow (Table 2). Once more saline bare areas and sand flats scored no flow (Table 2).

Beaches and mangroves had a high flow of tourism and recreation. For the intrinsic values, beaches (54%), mangroves (49%) and water body areas (48%) were high followed closely by other vegetation (46%), palm trees (44%) and settlements (32%). Saline bare areas again scored a very low flow for this service.

Table 4
Summary of the statistically significant one way MANOVA-test for the assessment of regulating ES flows from the selected LULC with high scores based on participants' profiles.

Regulating Services	LULC with high score	Mean score of flow by community practitioners	Mean score of flow by researchers/academics/managers	Aggregate mean scores of flows	F-Value	P-Value	η^2
Erosion Protection	Mangroves	4.7	4.3	4.6	(8,56) = 3.46	0.003	0.331
	Other vegetation types	3.7	2.8	3.5			
	Settlements	2	1	1.8			
Carbon Sequestration	Mangroves	4.3	4.5	4.3	(2,62) = 0.18	0.833*	0.006
	Other vegetation types	3.0	3.0	3.0			
Flood Protection	Mangroves	4.2	4.1	4.2	(2,62) = 0.93	0.398*	0.029
	Other vegetation types	3.4	2.8	3.2			
Nutrient Regulation	Mangroves	3.7	4.2	3.8	(3, 61) = 1.32	0.275*	0.61
	Other vegetation types	3.0	2.7	2.9			
	Water mass	2.1	1.8	2.0			

*Results not statistically significant.
η^2 – Partial eta-squared.
n = 65.

Like in the other classes of ES, a one way MANOVA was conducted to test if the scores given by the participants varied based on their profile, results showed that differences were statistically significant for all the ES assessed except for the intrinsic values of the various landscapes which did not show any statistically significant differences in the outcomes (Table 5).

3.2.2. Spatial distribution of ES flow

Results from combining LULC data (Fig. 2) and the matrix scores (Table 2) for ES flow are shown below (Fig. 3). The different colours in the maps represent the spatial distribution of ES flow from the three different LULC mapped in this study with dark green representing very high flow and rosy no flow.

4. Discussion

This study revealed that the flow of ES varied strongly between and also within the LULC types. Indeed, Jacobs et al. (2015) mention that the matrix approach allows the analysis of complex situations, where ES assessment and data are scarce, and information is required to contribute to discussions and decisions, as is the case for the Mida Creek study. Mapping is also an important tool that helps to take into consideration socio-cultural realities of communities, regions, landscapes and ecosystems (Plieninger et al., 2013; Ryan, 2011). The process enables community participants to present their views, showing managers the need to empower local people and other stakeholders to participate in decision making (Stewart et al., 2008; Garcia-Nieto et al., 2015). Indeed, one aspect of this study, that is of particular interest, is the differences between how the representatives from the community scored the flows of ES relative to the scores from the representatives for research/academia/management. Thus, community practitioners generally showed higher and statistically significant differences from the researchers for provisioning services. For example, from the list presented in Tables 2 and 3 (in italics), *medicine* is mainly obtained from other vegetation types, particularly, the neem tree which is claimed to cure over 40 ailments (Mondal and Chakraborty, 2016). With regard to mangroves, Revathi et al. (2013) have listed over 32 diseases and conditions that can be cured with mangroves; although for Mida Creek, Dahdouh-Guebas et al. (2000) listed only 5 treatable ailments using mangroves. *Honey* production in the creek is higher in the mangroves, probably because conservation groups have supported this activity as a non-destructive exploitation of resources (Trott, 2013), and there is no

Table 5
Summary of the statistically significant one way MANOVA-test for the assessment of flow of cultural ES from the selected LULC with high scores based on participants' profiles.

Cultural Services	Land use/scape with high score	Mean score of flow by community practitioners	Mean score of flow by researchers/academics/managers	Aggregate mean scores of flows	F-Value	P-Value	η^2
Education & Research	Mangroves	4.3	3.9	4.2	(3,61) = 6.74	0.001	0.24
	Other vegetation types	3.0	2.7	2.9			
	Water mass	2.5	3.6	2.8			
Cultural Shrines	Other vegetation types	3.3	2.6	3.1	(2,62) = 3.75	0.032	0.105
	Settlements	2.7	1.4	2.4			
Recreation & Tourism	Mangroves	4.0	3.8	4.0	(5, 59) = 4.93	0.001	0.295
	Other vegetation types	3.0	2.4	2.9			
	Water mass	3.2	3.7	3.3			
	Beaches	4.3	3.8	4.2			
	Settlements	3.0	1.6	2.7			
Intrinsic Values	Mangroves	3.0	3.5	3.2	(6, 58) = 1.66	0.147*	9.98
	Other vegetation	3.0	2.9	3.0			
	Water mass	3.0	3.3	2.9			
	Beaches	3.3	3.2	3.3			
	Palm trees	2.9	2.6	2.8			
	Settlements	2.8	2.2	2.6			

* Results not statistically significant.
η^2 – partial eta-squared.
n = 65.

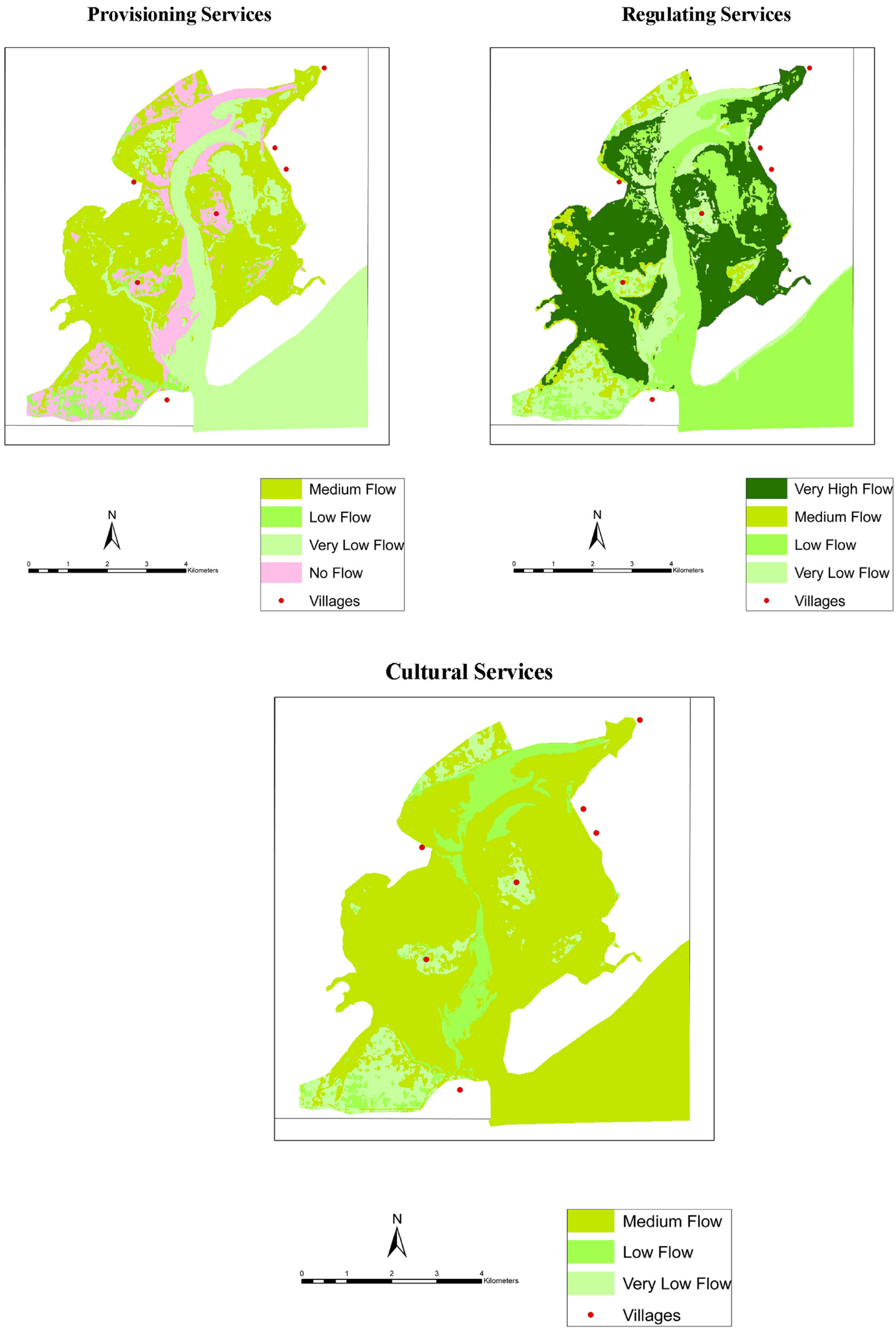

Fig. 3. Maps showing the spatial distribution of ES flow for Provisioning, Regulating and Cultural Services in Mida Creek.

evidence of economic costs such as licences, although ecological costs such as fire for harvesting have yet to be examined. There is also a high flow of *fisheries* for seafood and bait supplies from both the mangroves and the waterbody areas, as these are the breeding grounds and the natural habitats for marine fauna (Laura et al., 2013).

However, perhaps surprisingly, the researchers have given a higher flow for *firewood*, *charcoal* and *construction poles* from the mangroves than the community stakeholders (See Table 3). Although the preferred source for building materials is from the mangroves, charges and other restrictions to harvesting have encouraged the community to use other more available vegetation types such as casuarina trees (Dahdouh-Guebas et al., 2000). Palm trees are also readily available, but they have a lower overall strength and durability for construction (Ashmore and Fowler, 2009) and are generally grown for vegetable oil (Verheye, 2010). All these vegetation types are used for firewood. It is probable that the researcher community have given a high flow for wood products in the belief that mangroves are still relied on heavily by the local community, despite the many restrictions.

Mangroves have a high score for the provision of all the regulatory services shown in Table 4 (in italics), *erosion protection, carbon sequestration, flood protection* and *nutrient regulation* when compared with the other LULC types. The intertwined rooting complex of mangroves, especially the *Rhizophora* species, stabilizes sediment by reducing erosive capacity of water passing through the root system (Wolanski et al., 1993). Palm trees and most of the other vegetation types that grow in patches would not match mangroves in offering this service, and the same could be said for flood control. For carbon sequestration, previous studies have indicated that per hectare, mangrove forests store up to five times more carbon than most other tropical forests around the world (Nellemann et al., 2010). A study conducted by Cohen et al. (2013) showed that the mangroves of Mida Creek have above-ground carbon stock potential of 0.116 megatons. In Gazi Bay Kenya, there is a mangrove carbon market project which covers an area of 117 ha, and the estimated above and below carbon sequestered is 178,250 tons while annual sequestration is 4030 tons per year. It is expected to deliver a total $ 13,000 worth of carbon credits per year (Plan Vivo, 2010). Such a project could be replicated in Mida Creek with potential for economic benefit to the local communities. Mangrove systems are an important protection against extreme phenomena, like tsunamis (Das and Vincent, 2009). Indeed, the tsunami event of 2004 that struck Asia, also affected the East African coast, and it was widely reported that the mangrove and coral reef systems played a critical role in reducing the impact of the tsunami wave (Das and Vincent, 2009).

Considering the differences between the community practitioners and those from research, academia, and managerial categories (Table 4), the flow for regulating ES tends to be higher from the community practitioners for *erosion* and *flood protection* and also for *carbon sequestration* and *nutrient regulation* with regard to other vegetation types. However, the researchers have a strong flow from the mangroves for both *carbon sequestration* and *nutrient regulation*. This shows that different groups have different interests and knowledge about the natural resource and the ES they provide (Lamarque et al., 2011). Nonetheless, the local communities clearly understood that mangroves are an important ecosystem for shoreline protection.

Finally, with regard to the cultural ES, mangroves have a strong flow for *education and research*, *recreation and tourism*, and *intrinsic values* (Table 5 in italics), but nothing for *cultural shrines* which are confined to the adjacent land. Strikingly the local community generally has higher flow scores than the researchers for most aspects of these ES. Tourism is considered an important source of income for the Kenya's coastal population and a revenue source for the government of Kenya (UNEP, 2011). The high flow from mangroves for *education and research* is consistent with studies that have shown that world mangroves attract a lot of researchers, students and schools who want to understand and learn about this system (UNEP, 2011). In the case of *recreation and tourism*, the Dabaso board walk provides access to the mangroves for visitors, albeit for a fee. Indeed, the majority of the community members present during the survey engage in eco-tourism activities like canoe riding and tours along the mangrove boardwalks within the marine reserve. Nonetheless, the highest flows are for the beaches, probably due to their free access for all the communities of Watamu, allowing them to sell excursions and curios to tourists. In the case of the *intrinsic values* there are no significant differences between the local community and the researchers. Indeed, the results for cultural ES at Mida Creek are similar to those for other studies where, for examples, Sohel et al. (2015) and Hartig and Staats (2006) deduced that people showed greater preference for natural landscapes as a providers of cultural services. The high flow of cultural ES from *cultural shrines* occurs for other vegetation and settlements. However, this is a complex topic, as most of the people who visit the shrines (Mganga) do not want to be identified. The elders of the communities informed the attendants of the workshops that most of the shrines within the settlements are mosques. The majority of the people living around Mida Creek are from the Giriama community, who are predominantly Muslims (Dahdouh-Guebas et al., 2000).

In conclusion, the mapping of ecosystem services flow in Mida Creek has addressed some of the recent criticisms levelled at the use of ES mapping for decision making in resource management (Crossman et al., 2013; Fisher et al., 2009). Firstly, most studies have focused on the global scale (Naidoo and Ricketts, 2006), which is not easy to transfer to decision making at the national, sub-national scale and local scale (M.E.A, 2005a, b). Secondly, very little attention has also been given to marine and coastal areas (Maes et al., 2012). Consequently, there has been a lack of information relevant for local-scale decision making (Turner and Daily, 2008). In particular, studies are scarce that focus on LULC to show the spatial distribution of ES at the interface between terrestrial and aquatic system. The Mida Creek study has used a matrix approach to develop spatial maps of ES flow, to identify important ES, and to establish opinions of experts on ES flow (Burkhard et al., 2009). The matrix approach tested in this study has been criticized for reasons relating to its reliability, the lack of transparency in survey methods, insufficient agreement among survey participants and limited validity (Jacobs et al., 2015). Nevertheless, this approach has gained popularity (Jacobs et al., 2015) because it is efficient, fast, accessible and easily adaptable. Several measures can be taken to address the challenges facing the methodology, *i.e.* careful selection of participants with at least some knowledge of ES, a clear description of all assessed ES, use of very specific questions and the provision of additional material such as maps, satellite images, photographs (Jacobs et al., 2015). To address some of these challenges in the Mida Creek study, satellite images have been provided with the LULC of the study area and in some cases photos of the land cover classes. In addition, debriefing sessions have been held with the respondents to find out the reasons for their scores. As a consequence of this study on “Mapping of ecosystem services flow in Mida Creek”, the community of stakeholders who depend on the natural resources of this natural reserve have a much better awareness of the ES it provides, which can only be beneficial for its future management, as well as providing a template for management strategies at the local scale for other coastal regions of Kenya and elsewhere.

5. Conclusions and recommendations

This study shows patterns in ecosystem services flow from the different LULC in Mida Creek.

A) **Stakeholder perception**: Overall, it is important to recognize various types of knowledge and perceptions, since they play an important role in conservation and natural resource management. (Bhattachary et al., 2005). Integrating different perceptions and knowledge into environmental decision making can improve the understanding of resource and ecosystem dynamics.
B) **Flow of ecosystem services**: The highest flow of wood products was from other vegetation, although the community prefers mangroves and palm trees. Mangroves have high capacity for regulating services, while there is no flow of ecosystem services from saline bare areas and sand flats. Therefore, it is important to know the spatial distribution of ES provided by the different ecosystems to provide spatially relevant conservation mechanisms. This study offers information that can be used for the initial stages of integrated natural resource planning. Though the matrix model has been challenged, it is important since it has enabled community members as well as researchers/academics/managers to identify opportunities and threats to sustainable use of resources.

Based on the observations from this study, future recommendations are:
at the global scale;

More studies on ES assessment are needed, especially in developing countries where communities depend on natural resources for their livelihoods. Future studies should focus on ecosystem services benefitting areas, and the addition of more indicators for water bodies and saline bare areas to find out how they score against other systems.

at the local scale;

(i) **provisioning of alternative energy sources and building materials**: A mechanism should promote and support households to plant casuarina which is a non-indigenous, non-invasive tree in their farms as a viable alternative to mangroves. This would enhance the well-being of the communities living around the reserve and reduce pressure on the protected mangroves as a source of building and construction materials.
(ii) **alternative uses**: promotion of activities such as apiculture, a non-extractive use of the protected area, could be achieved by "labelling" and marketing to increase the value of honey from the reserve

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2017.02.013.

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