International Journal of Environmental Planning and Management
Vol. 3, No. 1, 2017, pp. 1-9
http://www.aiscience.org/journal/ijepm
ISSN: 2381-7240 (Print); ISSN: 2381-7259 (Online)

Management of Gum Arabic Production Potentialities in the Gum Belt in Kordofan, Sudan

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Abstract

The objectives of this paper are to identify the potential production areas, investigate current gum Arabic production systems, analyze land use/land cover change and distribution of *Acacia senegal* (*Hashab*) trees and addressing the constraints pertinent to gum Arabic production in Kordofan. The study used a composite of research methodologies and tools including primary and secondary data gathering, remote sensing and terrestrial data sets, and social valuation. The findings revealed a promising resource base with regard to gum Arabic production potentialities. In view of that, remotely sensed data expressed five classes of land use/land cover, in which forests dominated by *Hashab* tree class with a considerable share (21%) and increasing trend during the last two decades. The results of social survey indicated that *Acacia senegal* base agroforestry is a dominant (76%) land use system in Kordofan. The overall assessment revealed that the gum arabic sub-sector in Kordofan has remained underdeveloped in comparison to its huge potentialities due to some serious constraints, in terms of environmental, socio-economical and institutional ones. Finally, the paper concluded a set of guidelines and tools to fill up the technical and institutional gaps for improving gum Arabic production potentialities.

Keywords

Agroforestry, *Acacia senegal*, Remote Sensing, Land Use, Land Cover, Gum Arabic, North Kordofan

Received: February 7, 2017 / Accepted: April 7, 2017 / Published online: June 14, 2017

1. Introduction

Sudan is the world's largest producer of gum Arabic, providing a bout (78%) of international gum market [8]. Gum Arabic production is principally practiced in the traditional rainfed agriculture of western and central Sudan. The gum Arabic producers involved in gum Arabic activities are estimated up to 20% of Sudan's population, or around 6 million people, and are among the poorest and most vulnerable to food insecurity [4] [8]. The bulk of gum Arabic resource base is concentrated within the semi-arid zone and low rainfall woodland savannah between latitudes 10° and 17° N. The area is classified as one of the most vulnerable region regarding desertification and land degradation which diminish and alter the gum Arabic belt boundaries across the country [12] [13]. Some recent studies argued that gum belt has experienced vigorous transformation in gum Arabic farming systems [9]. In view of that, climate change coupled with over cultivation, over grazing and extensive clearance of

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forests increase the vulnerability of the ecosystem to desertification processes causing serious threats to the woodlands, gum Arabic gardens and rangeland [1] [2]. *Acacia senegal* has effectively been 'domesticated' through the development of an indigenous bush-fallow system, whereby agricultural cropping and forest regeneration are practiced in sequence. With the completion of the forest rotation (the bush period), the land is cleared for crop.Other Acacia-based agroforestry systems also exist in the area beside pure stands for gum Arabic production [5] [9].

Generally, the resource base of gum Arabic production systems are confronted by several and complex interacting factors, expressing themselves in terms of environmental, socio-economical and political factors. These interaction influenced production and productivity and in most cases have led to consecutive deterioration in the resource base. Therefore, strong arguments have emerged for this paper to investigate the gum Arabic production potentialities in the gum belt of Kordofan.

2. Objectives

The objectives of the current paper are:

1. Identification of the potential productive areas of gum Arabic in Kordofan.
2. Investigation of current gum Arabic production systems.
3. Recognition of constraints pertaining to gum Arabic production.
4. Assessment of land use/land cover and distribution of *Acacia senegal* trees in Kordofan's gum belt.
5. Developing guidelines and tools for proper management of gum production and potential in Kordofan region.

3. Materials and Methods

3.1. Description of Study Area

The study was conducted in North Kordofan (A) and West Kordofan (B) States which is located within the arid zone of central Sudan between latitudes 9° 30' and 16° 24' N and longitudes 27° to 32° E. The Region is characterized as one of the most vulnerable area in the country concerning desertification processes. The two study areas are located within the gum belt. Area A is located in the northeast part covering an area of 110483 ha, while area B is located in the south-west a part of the gum Arabic belt covering an area of 153722 ha (Figure 1). The study sites are located in the Sahel zone, which refers to an ecological zone situated between the Sahara to the north and the Sahel zone to the south [1]. The mean annual temperature varies between 28° and 30°C. The coldest months are December and January with mean temperatures of 14.1°C and 13.5°C, respectively, and the hottest months are April, May and June with an average mean temperature exceeding 30°C [15] [16]. The rainy season is from June to October with the highest rains in August. Average rainfall estimated is 250-400 mm. The length of the rainy season depends on the degree of latitude [17]. The main activities are rain-fed agriculture and livestock herding, also the community composed from as rural (50%), urban (34%) and nomads (16%) with an annual growth rate of 1.45% [1]. The woody vegetation is sparse and denser which is found only in the *wadi* systems. Common tree species are *Acacia senegal*, *Acacia mellifera (Kitr)*, *Acacia tortilis (Seyal)*, *Commiphora ssp*., *Balanities aegyptiaca (Hejlej) and Lannea humilis (lyon)*. The main grasses in the area include annual grasses namely *Echinochloa colonum, Aristida mutabilis, Dactyloctenium aegyptium, Tribulus longipetalous and Eragrostis termula.*

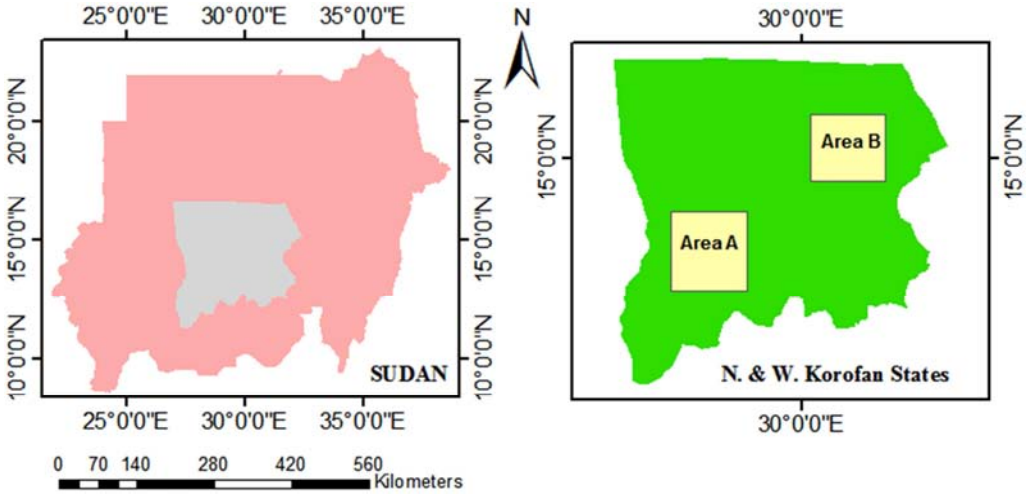

Figure 1. Map of the study area.

Source: Developed by authors, 2016

3.2. Data Collection

The current paper was based on primary data constitutes amalgamation of remote sensing and terrestrial inventory, in addition to social data. However, secondary data was gathered from recent publications and related sources.

The study integrated data from different sources and used different methods and approaches to analyze the long term land use land cover changes and trends during the previous four decades in Kordofan gum Arabic belt. The study used imageries from different satellites (Landsat and ASTER) and multi-temporal dates (MSS 1972, TM 1985, ETM+ 1999, ASTER 2007 and Land sat8 2015) acquired in dry season. Table (1) lists the source of each image including year of capture and spatial resolution (m). The imageries were geo-referenced and radiometrically corrected by using ENVI-FLAASH software.

Field work surveys for ground control points (GCPS) was conducted from Kordofan region in February (2015). Also additional secondary data such as socioeconomic and climate data were used to analyze the driving forces and effects of physical factors in the study area. The ERDAS (Earth Resources Data Analysis System) Imagine version 9.1 and ENVI (Environmental Visualization) software version 4.5 were used for image processing, masking and classification (supervised classification using maximum likelihood method).Meanwhile, ArcGIS 9.1 was employed for database development, spatial data analysis, producing thematic maps and extracted spectral reflectance.

The primary data of the social survey were collected based on simple random sampling technique via structured questionnaire designed and distributed among 100 respondents(farmers) in *Um Semmaia, Um Habelia, El Himmera* and *Nabag* villages Kordofan State in gum Arabic belt.Furthermore, focus group discussion with key-informants from villages and institutions were conducted. Microsoft Excel and SPSS programmes were used for descriptive statistical analysis.

Table 1. Characteristics of multi-temporal imagery.

Satellite	Acquisition date	Resolution (m)
Landsat Multispectral Scanner (MSS)	09.11.1974	57x57*
Landsat Thematic Mapper (TM)	19.11.1985	30x30
Landsat Enhanced Thematic Mapper plus (ETM+)	19.111999	30x30
ASTER-TERRA	22.10.2007	15x15
Landsat 8	27.03.2015	30x30

*Resampled from (79x79) mat EROS Data Centre

4. Results and Discussion

4.1. Potential Productive Areas of Gum Arabic in Kordofan

The spatial distribution map (Figure 2) was intended to display the most potential areas with regard to gum Arabic production across the gum Arabic belt in Kordofan region. The map specified nine geographical sites that are characterized by highly populated *Hashab* tree in both pure stands and Acacia based agroforestry systems. Under this context the pure stand *Hashab* forest is represented by *Elhemira* and *Eldamokeya* where the first site is recognized to be tapped by unsettled family labors inhabiting Elobeid city. *Eldomakeya*, the second site; has been reserved as a gene bank for research purposes besides its contribution to the livelihood of local communities at *Taggat* Administrative Unit. The tree based agroforestry system is the dominant practice, represented by *Iyal Bakheit*, El Rahad, Um Ruwaba and Abu Zabad areas. In this system, the producer used to cultivate multi crop farming (sesame, groundnut, millet, sorghum, roselle and watermelon seeds) rotated with *Hashab* trees and produce each crop on the basis of its relative profitability within the system. It is worth to mention that the potentialities of gum Arabic production within this system are not affected, because it has never been contradicting with the calendar of other agricultural crops.

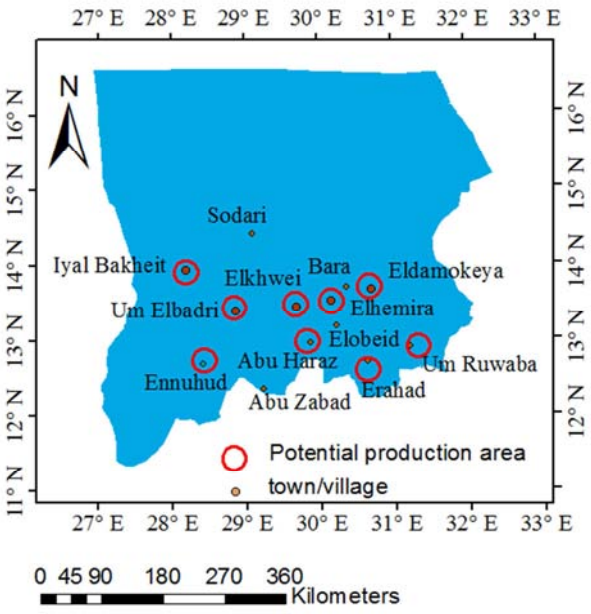

Figure 2. Spatial distribution map of some potential production areas of gum Arabic in Kordofan.

Source: produced by authors

The results showed that an average of 400g is obtained from a single trees; this goes in a line with [3], who argued that the

productivity was estimated to be 250g of gum per year from seven pickings, while a good yielding tree may produce up to 500 -600g on average. According to [14] the annual yields from young trees ranged from 188 to 2856 g (average 900 g), while older trees produced from 379 to 6754 g (average 2,000 g).

The study also revealed that 245 trees per ha are found in pure stands of *Hashab* trees produce 450 g per tree on average. The density of *Hashab* trees varies from stand to another depending on management practices. In this respect stand under reserved forests reaches up to 450 trees per ha, whereas in private gardens the density is about 100 - 125 tree per ha as minimum, whereas it could reach 625 trees per hectare as high average. The spacing is accordingly varying from 4 x 4 meters to 9 x 9 meters [7]. The production in the reserve forests is characterized as higher than in individual farmer's gardens due the variation in stocking density. [6]. In this regard is concluded that good management practices might improve gum productivity.

Study results revealed that tapping of gum trees starts after the fourth year onwards by coppiced trees until year 15 when the yield starts to drop. However, the gum starts to exude after a period which varies greatly from tree to tree and normally it starts after four weeks after tapping.Good gum yield depends on a number of environmental and socio-economic factors such as high temperature, good amount of rainfall both in quantity and distribution, suitable time for tapping, freedom from grazing, insect pests and diseases, in addition to good prices. Rich accumulated indigenous knowledge about *Hashab* husbandry is quiet clear in the study area, which represents a valuable opportunity that supports the production potentiality and sustains the resource base in the area.

4.2. Current Gum Arabic Production Systems

Study results showed three main categories of farmer regarding gum Arabic production activities these are producers (70%), tappers (8%) and collectors (21%). Concerning land tenure, 99% of respondents owned *Hashab* gardens. It is very common in the area that gum gardens are allotted to land ownership, therefore landless people have no right to establish trees. Different land use systems in Kordofan are practiced; mainly farming (24%), pure gum Arabic production (18.7%), agro-silvo pastoral (45%) and bush fallow system (10.7%). The interpretation of these findings is that the Acacia Senegal base farming systems is the dominant land use system as it appears in pure gum arabic stands, agro-silvo pastoral and the bush fallow system (76%).

Results regarding labor force in gum production activities proved family labor (60%), hired labor (24%) and group work (*Nafeer)* (16%), meanwhile, the role of women has become observable. About 85% of the rural women participate in gum Arabic production chain, mainly in cultivation, planting, gum picking and collections.

Whereas, tapping tools study indicated that 46% of respondent use the traditional small axe for tapping the tree, 15% use *sunki*, 3% use *makmak* and the rest proportion use other available tool. This result is an indicator of the absences/ weakness of the extension services because many intermediate technologies were developed in the last two decades, but the adoption is quiet poor.

4.3. Methods of *Acacia senegal* Establishment

More than 50% of gum Arabic produced in Sudan is obtained from plantations or naturally regenerated stands. In the study area natural stands represents 30%, while the plantation stands represents 50%, besides combination of other methods represented 20%, as perceived by respondents. It is worth to mention that 75% of the producers obtain the seedlings from Forest National Corporation (FNC), while 25% get the seedlings from other organizations and village nurseries.

4.4. Constraints to *Gum arabic* Production

Gum Arabic production processes experience many constraints, which have reduced production in terms of quantity and quality resulting in price inconvenience to producers and other stakeholders at upper stream level. Some technical and institutional constraints hindering gum arabic production potentiality in area were also encountered during the field survey. These are conflicts over resources, insufficient information on the gum arabic resource base with national forest inventory (NIF) and national governmental strategies and plans.

Based on the group discussion conducted by the current study, the gum Arabic production has been constrained with several problems such as lack and poor management of village nurseries, traditional way of gum production (using of axe, collection tools and mal-cultural practices, low tapping intensity per trees and per area, lack of large scale production). In addition to, improper post harvest techniques (drying, use of plastic sacks and bags).

It is worth mentioning that some production sites are in remote areas compared to markets, with poor infrastructures and services These are: drinking water, storage facilities, means of transportation, extension, official finance, education and health units, limited sources of income, insufficient and unskilled labor force, traditional gold mining, rural-urban migration, lack of value addition activities fire hazards, tree locust & other pests.

4.5. Land Use and Land Cover Analysis in Gum Belt in Kordofan

Supervised classification using the maximum likelihood algorithm in ERDAS imagine 9.1 generated five main land use/land cover (LULC) classes for all imagery in the gum Arabic belt includes: bare and farm land, grass and bush land, forest dominated by *Hashab*, mixed woodland and residential area. These land use/land cover classes were derived from imagery dated 1972, 1985, 1999, 2007 and 2015 for the two study areas A and B. The classification results are shown in table (3) and table (4), representing the land use/land cover classes in year 2015 in the study areas A and B as; bare and farmland (39.58% and 9.46%), grass and bush land (30.74% and 57.43%), forest dominated by *Hashab* (21.66% and 24.18%), mixed woodland (6.64% and 9.9%) and residential areas (1.97% and 2.30%), respectively. Forest dominated by *Hashab* ranked as third one in the two areas. The results indicate that forest dominated by *Hashab* and mixed wood lands have declined steadily during year 1972 to 2015. In contrast, the residential areas increased from year 1972 to 2015 in the two sites. Among the LULC types, forest dominated by *Hashab* and mixed woodland increased slightly during the period from year 1999 to 2015, from 17.83% to 21.66% and from 5.32% to 6.06%, respectively in area A; and from 21.29% to 24.18% and from 7.36% to 6.64%, respectively in area B. [1] has explained the increase of vegetation cover in the area due to the increase in rainfall and as a result of migration consequence which is often abandoned fields and reduced grazing pressure. The results indicate that the grass and bush land class constitutes the most coverage of land in the two studied area for the four dates, because the area is considered as main source of range lands and about two third of the livestock in Sudan are raised in the gum Arabic belt [10].

The forest dominated by *Hashab* class includes all *Acacia senegal* trees distributed in the forested area and under agro-forestry systems, in addition to the scattered ones in other land use systems. Due to the different spectral reflectance responses detected by earth observing remote sensing systems, the identification and separation between the five land use land cover classes in the areas are defined and extracted [11]. The agricultural lands during the dry season are usually found bare or contain dried residual of crops with similar spectral reflectance of grass; they merged together in one class during classification process. The same case was applied to grass and bush land, which appeared with the same spectral reflectance.

Table 2. Land use and land cover classes distributions during (1972-2015) in area (A) in gum Arabic belt in Kordofan.

Land use type	1972		1985		1999		2007		2015	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
1	15697.3	14.20	7310.0	6.62	39864.6	36.08	17870.0	16.17	43771.9	39.58
2	52409.5	47.43	67279.5	60.89	43614.2	39.47	59720.0	54.05	33990.8	30.74
3	32390.4	29.32	27299.7	24.70	19702.1	17.83	24146.9	21.86	23948.7	21.66
4	9408.2	8.51	7850.7	7.10	5877.7	5.32	6834.3	6.18	6692.04	6.05
5	577.8	0.52	743.2	0.67	1424.4	1.29	1911.9	1.73	2181.06	1.97

Where: 1 bare and farm land, 2 grass and bush land, 3 forest dominated by Hashab, 4 mixed woodland, 5 residential area

Table 3. Land use and land cover classes distributions during (1972-2015) in area (B) in gum Arabic belt Kordofan

Land use type	1972		1985		1999		2007		2015	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
1	19534.8	12.70	23293.1	15.15	15047.3	9.78	12936.1	8.41	14557.9	9.46
2	65574.7	42.65	74884.6	48.71	93406.0	60.77	86710.0	56.41	88364.6	57.43
3	49433.8	32.15	41631.1	27.09	32724.8	21.29	37221.3	24.21	37200.9	24.18
4	18336.7	11.93	12888.5	8.38	11318.7	7.36	15354.2	9.98	10209.4	6.64
5	842.4	0.54	1025.1	0.67	1225.6	0.79	1500.9	0.97	3538.3	2.30

Where: 1 bare and farm land, 2 grass and bush land, 3 forest dominated by Hashab, 4 mixed woodland, 5 residential area

The land use/land cover maps for the imagery representing the two sites were showed in figure (3) and figure (4). Comparison of the maps for the two areas reflects the different changes between the land use/land cover classes during the last four decades (1972-2015) in gum Arabic belt in Kordofan. New areas were covered by *Hashab* and formerly covered areas disappeared.

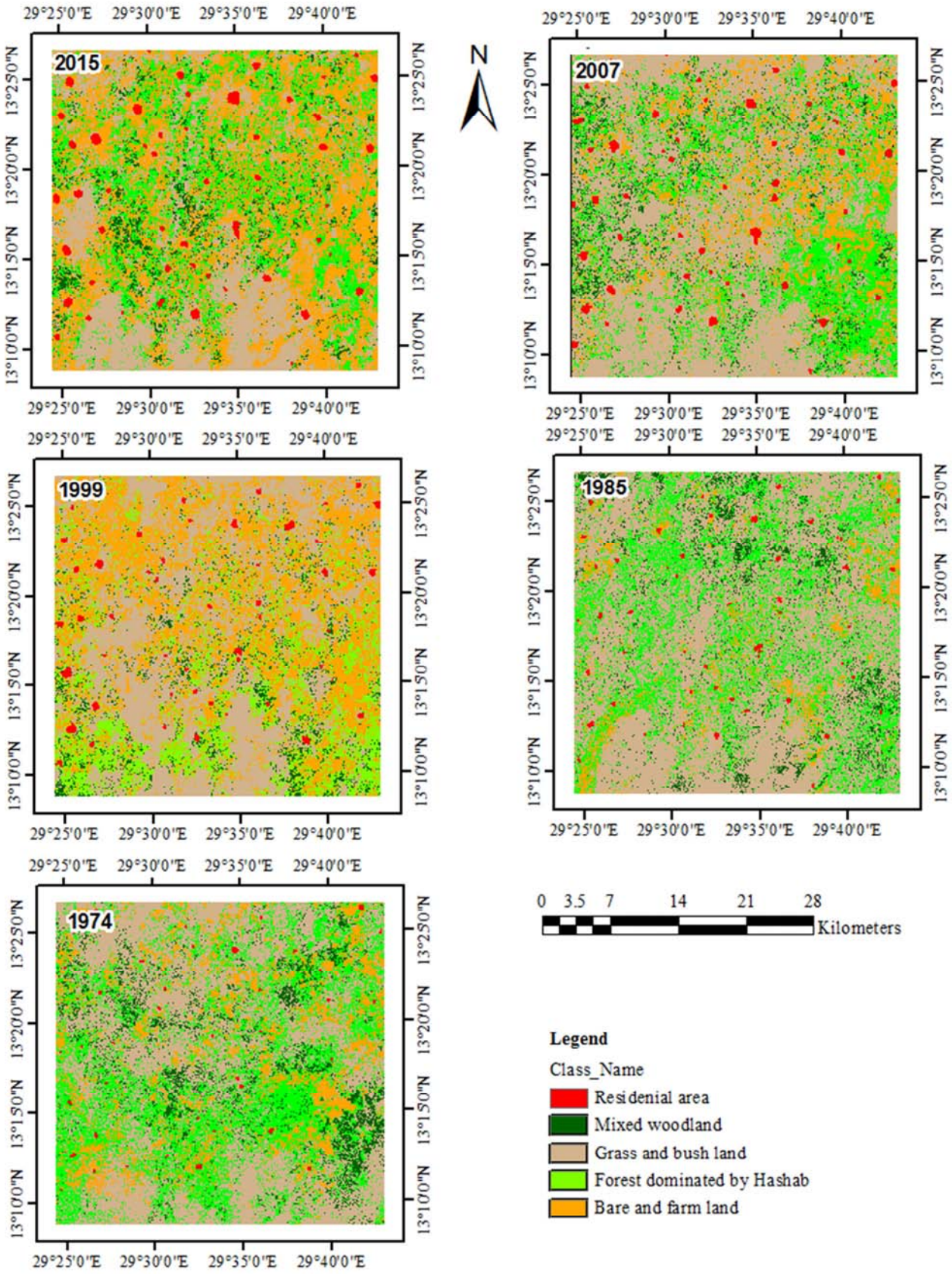

Figure 3. Land use and land cover maps in area (A) for 2007, 1999, 1985, 1972 and 2015 based on maximum likelihood classification.

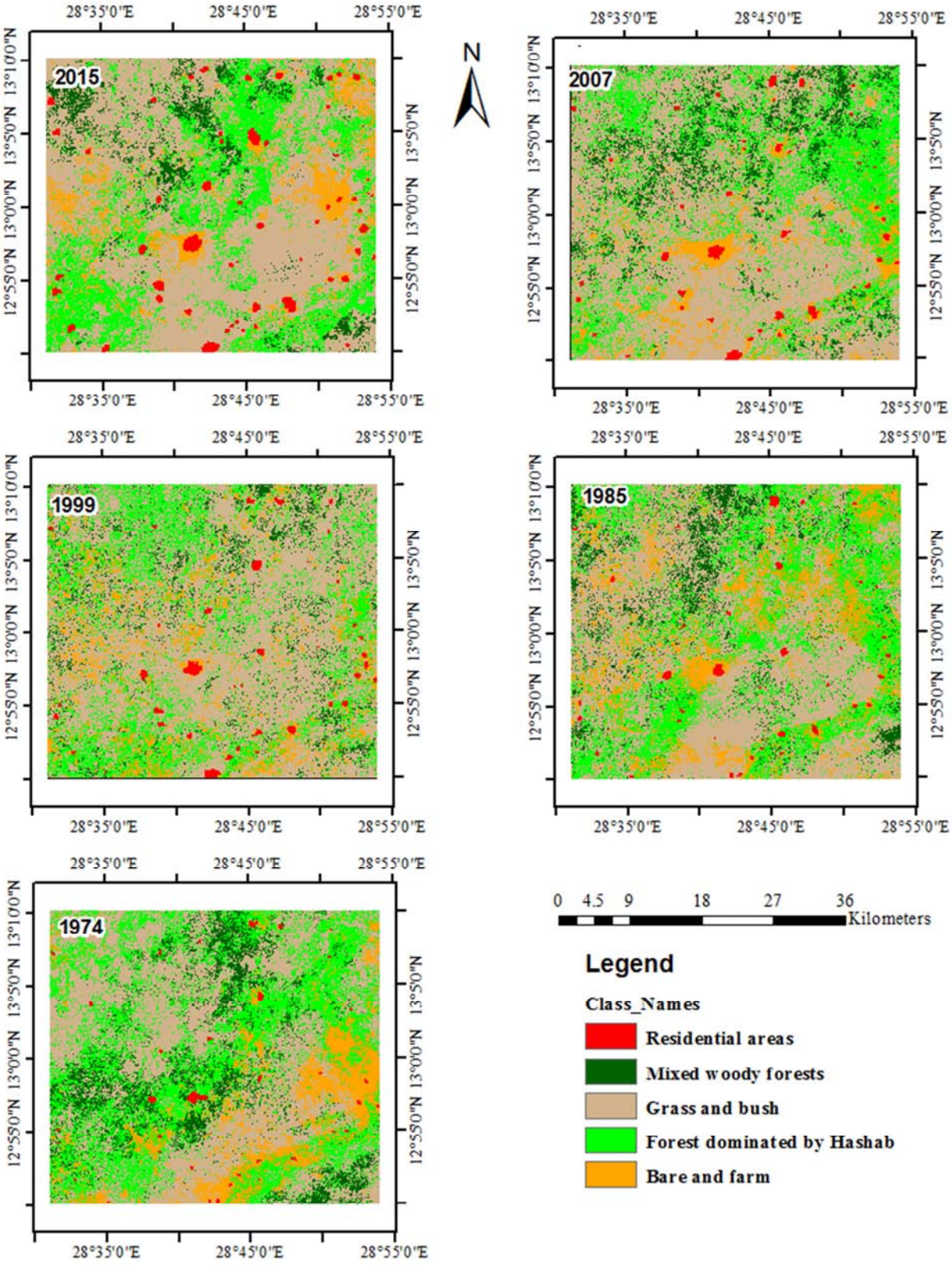

Figure 4. Land use land cover maps in area (B) for 2007, 1999, 1985, 1972 and 2015 based on maximum likelihood classification.

The conversion to grass and bush land from other land use land cover classes was the main trend of the land use land cover change in the two areas (A) and (B). Land use/land cover in Kordofan was affected by many problems due to lack of adequate policy framework, the absence of unified legislation and inadequate consideration of the socioeconomic factors, which play a vital role in land management and conversion.

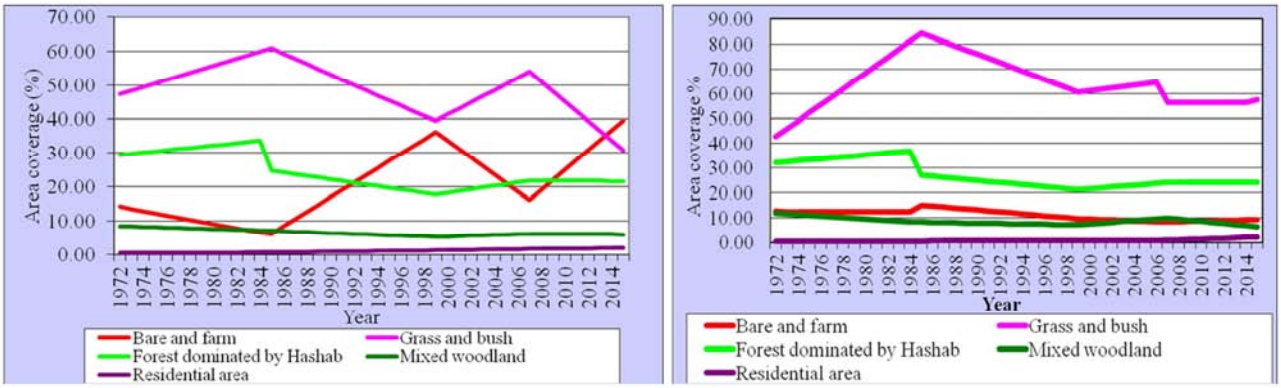

Figure 5. Land use land cover distribution trend in Kordofan region 1972 -2015 in area A (in left) and area B (in right).

The dynamics and trends of the LULC classes during the last four decades in Kordofan indicate various changes.

5. Conclusion and Recommendations

The paper concluded that the gum Arabic subsector in Kordofan has remained under developed in comparison to its huge potentialities because of some constraints, such as environmental, socio-economic and institutional ones. Accordingly, a set of recommendations and guidelines were proposed by the current paper for the development of the gum Arabic production potential as fallow:

1. Gum Arabic subsector should receive special consideration in the government strategies and plans together with other actors to survey, manage and conserve the resource base.
2. Surveying of production and consumption of gum Arabic commodity in order to link their supply and demand to the forest potential within the national forest inventory (NFI).
3. Resolving conflicts on land tenure systems via set up of obvious regulations on the basis of win-win arrangements agreed upon between different stakeholders.
4. Adoption of good practices concerning nursery operations, land preparation and tapping techniques.
5. Improvement of infrastructures and services (water, storage, transportation and feeder roads) at the gum Arabic production areas.
6. Encouraging developers of intermediate technologies to design suitable tools for gum Arabic tapping, collection and primary processing.

Acknowledgement

The authors acknowledge the financial and technical support for conduction and publication of this research provided by CHAINS Project (Chances in Sustainability-Promoting Natural Resource Based Product Chains in East Africa, funded by the German Federal Ministry of Education and Research (BMBF) under the project-ID 01DG13017. The responsibility for the contents of this publication is with the authors.

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