Chapter 2
GIS and Remote Sensing-Based Forest Resource Assessment, Quantification, and Mapping in Amhara Region, Ethiopia

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Abstract World forest resources are continually depleting. Assessing and quantifying the current forest resources status is a prerequisite for forest resources improvement planning and implementation. The objectives of this study are to assess, quantify, and map forest resources in the Amhara National Regional State, Ethiopia. GIS, GPS, and Remote Sensing technologies were applied for the study. As a result, forest distribution map is prepared. Most of the forest covers were found along the lowland belt of Mirab Gojam, Awi, and Semen Gonder zones bordering the neighboring country, Sudan and the Tigray and Benishangul-Gumz regions. The total forest cover of the region is 12,884 km^2, that is, about 8.2 % of the total land area. Including bushlands, it is about 21,783 km^2, which is about 13.85 %. Woodlands, natural dense forest, riverine forest, bushlands, and plantations are 740,808, 463,950, 20,653, 889,912, and 62,973 ha in area with percentage coverage of 4.71, 2.95, 0.13, 5.66, and 0.40 respectively. GIS, GPS, and Remote Sensing were found to be important tools for forest resource assessment and mapping.

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2.1 Introduction

The Amhara National Regional State (ANRS) is located in the northwestern part of the country, Ethiopia. It is situated between 8° 45′–13° 45′N latitude and 35° 15′–40° 20′E longitude. The region covers about 157,127 km^2. It has common boundaries with four national regional states of the country, Oromiya in the south, Afar in the east, Tigray in the north, and Benishangul-Gumuz in the west. It also shares a common boundary with the neighboring county, Sudan, in the west. According to the 2007/08 census, the region has about 20,650,419 people. About 87.3 % of the population lives in rural areas and 12.7 % lives in urban areas. Agriculture and livestock production are the main farming systems of the region. Forestry is the other product of the region that the population depends on for domestic firewood, construction, and utility pole contributing to the country's economy.

The region has a wide biodiversity of flora and fauna. However, increase in the population, livestock pressure, and increased demand for arable land are causing a significant depletion of forest resources. Loss of cover results in high rate of soil erosion, loss of soil fertility, and degradation of water resources. These factors in turn, adversely affect agricultural productivity. Soil fertility is further depressed where animal dung and crop residue are diverted for fuel to compensate for the shortage of wood. The cumulative effect of this chain of events is reflected in the prevailing land degradation, poor economic performance, and accelerated poverty.

The regional government with the Bureau of Agriculture (BoA) has made great efforts to manage the remnant forests as regular and priority state forests, community or privately owned forests. Studies conducted to identify and quantify the forest cover of the region are limited. Even if there are studies, they were conducted a decade before and they could not show the current status of forest cover. Hence, this study was initiated to assess, quantify, and map the current forest cover status of the region using GIS and remote sensing techniques together with secondary and primary data at ground level.

Land use/land cover dynamics is an important landscape process capable of altering the fluxes of water, sediment, contaminants, and energy. Mainly caused by humans, impact of land use on water resources availability is high. Degraded watersheds tend to accelerate overland flow reducing soil moisture and baseflow recharge and increases sediment detachment and transport. Various studies used land cover mapping tools and methods to understand land use changes, inventory of forest and natural resources, as well as understand the changes in the hydrologic behavior of watersheds (Getachew and Melesse 2012; Mango et al. 2011a, b; Wondie et al. 2011, 2012; Melesse et al. 2008; Melesse and Jordan 2002, 2003; Mohamed et al. 2013; Heinen et al. 1989).

The specific objectives of the study reported in this chapter are to: (1) identify and quantify the forest resources of the region, (2) assess the spatial distribution of the regional forest resource and map it, (3) develop regional forest resource database and access information for decision makers, researchers, development practitioners, professionals, and others, and (4) assess the incense and bamboo resources of the region.

2.1.1 Scope of Study

The scope of the study was spatially limited in the Amhara National Regional State, which covers about 157,127 km^2. Objectively, the study is aimed to identify, quantify, and map the spatial distribution of forest resources in the region. The study is also charged with identifying incense potential areas in the region. Moreover, identification of bamboo resources and its potential sites is another area of concentration for the study. To conduct the study, field observations, collection of secondary information from the offices of agriculture at zonal and district level, ground level primarily GPS-based data, and satellite imagery were used.

2.2 Forest Resources in Ethiopia

The definition of forest is still ambiguous. According to FAO (2001) forest is defined as "land with a tree crown cover of more than 10 % and an area of more than 0.5 ha; the trees should be able to reach a minimum height of 5 m at maturity." UNFCCC (2006) also defined forest as a minimum land area of 0.05–1 ha, with tree crown cover more than 10–30 % and tree height of 2–5 m at maturity.

Ethiopia was rich in natural forests. Several authors and national or subnational inventory projects have carried out assessments and documented forest resources of Ethiopia. Close to 40 % of Ethiopia might have been covered by high forests as recently as the sixteenth century as historical sources indicate (EFAP 1994a). Another estimate put the original forest cover as a percentage of the total land area at 25 % compared with 48 % for the world (Earth Trends 2007). EFAP (1994a) notes that about 16 % of the land area was estimated to have been covered by high forests in the early 1950s, which declined to 3.6 % in the early 1980s and further declined to 2.7 % in 1989.

In the recent forest proclamation (No. 542/2007), high forests, woodlands, bamboo forests are recognized as forests. Following the definition of FAO (2001), the vegetation of Ethiopia that may qualify as 'forests' is natural high forests, woodlands, plantations, and bamboo forests, with an estimated area of 30.8 % (35.13 million ha). If the shrublands are added, the estimated cover is over 50 % (61.62 million ha). On the other hand, the recent data on forest resources of

Ethiopia reported in FAO (2010) puts Ethiopia among countries of the world with forest cover of 10–30 %. According to this report Ethiopia's forest cover (FAO definition) is 12.2 million ha (11 %). It further indicated that the forest cover shows a decline from 15.11 million ha in 1990 to 12.2 million ha in 2010, during which 2.65 % of the forest cover was deforested.

The growing need for fuelwood and agricultural land and overgrazing by livestock, coupled with improper forest and land tenure policies, are believed to be the major causes of forest degradation (Mulugeta and Melaku 2007). Extensive forest fires have also resulted in further losses. Dramatic deforestation has been associated with political transitions from the Imperial to the Derg regime, and especially from the latter to the Ethiopian People's Revolutionary Democratic Front (EPRDF) (Birhan 2009). Although such challenges had occurred at different times, it has been suggested that the northern Ethiopian Highlands had little forest in the past (Melaku 2003). Considerable afforestation has also been carried out notably in population centers. The government has also introduced a national tree planting campaign every year all over the country in which every person is encouraged to plant trees, with significant influence on the attitude of the population toward trees.

2.2.1 Forest Resource Base in the Amhara Region

At the national level, in Amhara region, modern tree planting using introduced tree species (mainly Australian Eucalyptus) started in 1895 when Emperor Menelik II (1888–1892) looked into solutions for alleviating shortage of firewood and construction wood in the capital, Addis Ababa. However, the historic rapid expansion of large-scale and community plantations occurred during the Derg regime, which resulted in the establishment of large-scale plantations. Several fuelwood projects funded by NGOs spread over the country with marked concentrations around big cities such as Bahir Dar, Dessie, Gondar, and Debre-Berhan. These plantations have often been established for supplying the huge demand for wood products in Ethiopia. But forest resources in the region have experienced so much pressure due to increasing need for wood products, conversion to agriculture, agricultural investments, incense investments, and settlements.

Few studies have been conducted to identify the forest resource of the region. Proceedings of the Ethiopian national forest cover workshop estimated the regional forest resource cover at about 5.91 % of the total area of the region. The assessment of the BoA was 0.48 % natural high forest, 4.2 % woodland, and 1.23 % plantation forests (Bane et al. 2008). Such studies proved that the regional forest resource is dwindling as the population growth and overgrazing pressure increased from day-to-day.

2.2.2 Forest Ownership

Federal Policy is now governed by the Forestry Development Conservation and Utilization Proclamation, issued in September 2007 (542/2007), which repealed Proclamation 94/1994. The policy recognizes two types of forests, state and private. State forests are any protected or productive forests owned by the federal or a regional state. Private forests are forests other than state forests that are developed by any private person and include forests developed by members of a peasant association or by any association organized by private individuals, investors, and governmental and nongovernmental organizations. In reality, no official maps exist, no management plans have been prepared, and not much has been done except budget allocation for guards. Regional and federal resources to delineate state forests and prepare management plans are extremely limited. As a consequence, considerable uncertainty exists as to whether the remaining forests in different parts of the country would be allocated for agricultural investment.

2.2.2.1 State Forests

State forests comprise the priority state forests, regular state forests, and project forests. The priority forests are 17, which include Wof-washa in North Shoa; Erkie in Oromiya; Yegof in Dessie Zuria; Denkoro Chaka in South Wollo; Woinye in North Wollo; Guna, Alemsaga, and Tara Gedam in South Gondar; Matebia, Angereb and Gundo Gordim in North Gondar; Kinbaba and Sekela Mariam in West Gojam; Yeraba and Abafelase in East Gojam; Kahtasa, and Elala Guangua in the Awi zone. There are some project forests which are found in the region as Gondar fuelwood in North Gondar, Dessie fuelwood plantation in South Wollo, and Debre Birhan fuelwood plantation in North Shoa. There are also about 124 regular state forests in different districts. Regional national parks, such as, Alatish and Semen parks in North Gondar, Denkoro Chaka from priority state forests in South Wollo are the other most important forest resources which are habitat for wild life.

2.2.2.2 Community and Private Forests

Private or community forests are forests that are developed by any private person or forests developed by members of a peasant association or by any association organized by private individuals, investors, and governmental and nongovernmental organizations. In Amhara region, the community forest is considered as public forestry developed and conserved by the Kebele (community) in the communal lands for the Kebele development purposes and conservation of degraded areas. There are also many forests that were developed and conserved by the government and have now been transferred to the community at Kebele level to be managed and used as community forests. Community and privately owned forests

are major sources of forest resources in the region. The availability of many communal lands in the rural areas can be used for tree plantation to diversify the forest cover. The severe shortage of wood for fuel, construction, and industries calls for huge forest development programs in the region, which creates an income opportunity for the rural poor.

2.2.3 Incense and Bamboo Potential

2.2.3.1 Incense Potential

Boswellia papyrifera is a deciduous multipurpose tree species known for its commercial product called frankincense or gum *olibanum*. It is mostly found in the lowland areas of the Amhara region which accounts for the lion share incense production in Ethiopia. Ethiopia is also one of the world's leading producers of incense, notably frankincense (product of Boswellia spp.) and myrrh and myrrh-like resins, products of Commiphora spp. (Lemenih and Teketay 2003). The production and trade volumes of gums and resins in Ethiopia have been increasing since the 1990s. Between 1998 and 2007, Ethiopia exported about 25,192 tons, an annual average of 2519 tons, of natural gums and resins with a value of 307,248,000 Eth. Birr equivalents to 34,138,670 USD (Lemenih and Kassa 2008).

In the western, northern, and northwestern lowlands of Ethiopia, the principal gum and resin producing species is *B. papyrifera*. In Metema District of the Amhara region, *B. papyrifera* accounts for 51 % of the woody plant density on average (Eshete 2002). Variations occur from site-to-site as a function of local climatic and anthropogenic factors. The density of *B. papyrifera* in the Metema area ranges from 64 to 225 stems per ha (Gebrehiwot 2003).

According to Tadesse et al. (2002) in the Metema district, *B. papyrifera* provide an annual yield of 6.7–451.4 g per tree, and others reported an annual yield of 207–352 g per tree. These variations in incense yield are attributed to tree size and tapping intensity. Generally, trees with bigger diameters at breast height (DBH) yield more incense than trees with smaller DBH. Similarly, increased tapping intensity increases incense yield per tree, although this has also been shown to affect tree vitality and reproductive biology.

Ecologically, the species is important since it can grow in areas where other trees fail to grow. The wood of Boswellia is used for poles and timber and for industrial manufacturing of matchboxes and boards. The leaves provide dry-season fodder, and the flowers are a good source of nectar for bees. Leaves, bark, and roots are also used in traditional medicines. The species is recommended for economic development and desertification control. Figure 2.1 shows woodlands dominated by *B. papyrifera* Species in Metema, Quara, and Belesa districts.

Fig. 2.1 Woodlands dominated by *Boswellia papyrifera* species in Metema, Quara, and Belesa districts, (*Photo* by Mulatie Mekonnen, December, 2011)

2.2.3.2 Bamboo Resource

The other most important species in the Amhara region is bamboo. There are two types of bamboo species in the region: highland bamboo (in Amharic, kerkeha) and lowland bamboo (in Amharic, shimel). Environmental and ecological differences of zones create conditions for growing these two different bamboo species. As their names indicate lowland bamboo grows in lowland areas of the region at altitude below 1800 m above sea level following the Abay basin and the Sudan border. The highland bamboo grows in the highland at altitude above 1800 m above sea level (Bereket 2008).

Planting bamboo and using it as a source of income has a very long history. The farmers are well aware of the local value of the resource. Especially, the highland bamboo in Awi, East and West Gojam zones is used for almost every utensil and furniture used in homes, fencing, construction, and agricultural equipment. The available resources are at good locations and near to potential markets such as the cities of Bahir Dar and Addis Ababa. The farmers have experience in propagation, harvesting, collection, and marketing the resource.

The lowland bamboo is also a type of important indigenous species. It grows well in the three zones (North Gondar, Awi, and West Gojam) and some in East Gojam. There was an estimated large lowland bamboo but due to lack of awareness of its economic value, it is being cleared and set on fire for farmland clearing. The current size of lowland bamboo resource is expected to be further reduced due to land clearing for resettlement of farmers from less productive areas. Figure 2.2 shows the highland bamboo species in Awi and West Gojam zones of the region.

Fig. 2.2 Sample highland bamboo species in Awi and West Gojam zones (*Photo* by Mulatie Mekonnen, February, 2012)

2.2.4 Opportunities and Challenges

2.2.4.1 Opportunities and Potentials

The Amhara National Regional State has wide agro-ecological or agro climatic zones, which are favorable for the growth of diversified flora species. The climatic variations help the region to have different and well-developed natural and planted forest resources; owned as state, community, and private forests. Currently, there is a huge local and export market potential for the forest products which can motivate the producers. Additionally, the attention of ecotourism in the region, the world-wide attention on global warming, and the presence of economically important plant species create a better chance for the forest resources of the region.

2.2.4.2 Challenges and Constraints

Although there are favorable agro-ecological zones in the region to develop and conserve forest resources; the region faces many problems. Currently, the prevailing population growth needs to satisfy wood resource and crop demand by encroachment of the forest lands. The rearing of large number of cattle and the grazing effect retards the growth of newly growing forest seedlings and saplings. Livestock trampling also leads to aggravated soil erosion which is unfavorable to tree and other vegetation growth. The problems are clear and understandable to every concerned body, but design of a system and community involved approach is lacking to alleviate the problem. There is limited strong forest protection and development policy and strategy. However, forest policies, action programs, strategies, and proclamation that can support and guide the forestry development have already been approved at the federal level in 2007. There is still no regional forest policy, strategy, and proclamation to control deforestation and illegal forest product movement and encroachments. Figures 2.3, 2.4, and 2.5 show deforestation

Fig. 2.3 Deforestation of economically important forest species in North Gonder Zone (*Boswellia papyrifera*)

Fig. 2.4 Forest deforestation and agricultural expansion (North Gonder Zone)

Fig. 2.5 Contribution of overgrazing for forest destruction (North Gonder Zone)

of economically important forests species (*B. papyrifera*) and other forests due to investment agricultural practices.

In general, the major challenges for the development and conservation of forest resources include: deforestation, poor forest management and utilization, agricultural investment on forest products (like incense), unbalanced gap between demand and supply of wood resources, poor survival rate of planted forest seedlings, weak institutional capacity, turnover of skilled manpower and lack of awareness of the community in forestry importance, and poor infrastructures.

2.2.5 Current Forest Management Situations and Mitigation Measures

Remnant natural large forests and woodland species are mostly found in the lowland areas of the region. They host diverse tree species of economic importance, the most important of which is *B. papyrifera* and other forest types like natural forests, woodlands, riverine, church, and lowland bamboo forests. However, due to agricultural expansion, overgrazing, fire, resettlements, and investment activities, these natural forests are becoming more vulnerable for destruction. Hence, it demands great care and proper forest management.

The regional BoA has promoted technology extensions through awareness creation and capacity building in the development and conservation of forest resources. Planting two trees per person at the end of the second millennium and three trees per person at the beginning of the third millennium have been taking place and planned to create awareness and promote plantation for forest recovery. Agroforestry practices such as woodlots, home gardens, trees on cropland, and farm boundary plantations are the most common practices on farmland. Currently, the most common tree species for community woodlots and private tree investments in the region are Eucalyptus spps., Acacia *decurrence,* and *Cupressus lusitanica*. Eucalyptus woodlots used to be extensively planted on farmland and increasing numbers of farmers are being encouraged to plant small on-farm woodlots in semi-urban areas where the returns from the sale of firewood and poles are attractive (EFAP 1994b; Zebene and Hulten 2003).

Although the region lacks its own forest policy, strategies, and proclamation the federal government forest policies, strategies, and proclamation are implemented in the management of the available forest resources. The regional government has also shown concern and allocated a budget for forest management and nursery extensions. Different development projects are assigned and oriented in supporting the development and sustainable utilization of the natural resources. But more than this should be done by BoA and other concerned bodies to conserve the remnant forest resource of the region.

2.3 Methodology

2.3.1 Materials and Methods

The materials used for this study were GPS, satellite image, GIS software, and topographic maps. Secondary data were also used from each district Agricultural Offices in addition to information from the experts. ArcGIS software was used to digitize the forest cover from the satellite imagery to analyze the results and to map the spatial distribution of the forest cover. GPS was used to collect GCP (ground control points) points and digital camera was used to take photographs that help for ground verification.

To carry out the study, on-screen digitizing from SPOT (5 m resolution) satellite imagery was used. Intensive GPS data collection and field observation were conducted for ground truthing. About 4800 GCPs and 820 pictures were taken from different locations for image interpretation. Field observations, discussions with experts, and secondary data assessments were done in more than 97 % of the regional woredas or districts.

Direct field observation and discussion with zonal and district experts were done to identify forest species. Secondary data from the district offices were also collected to crosscheck with the satellite image and was used as input for this chapter. Woreda experts, who are familiar with their forest resources distribution and type, helped in identification.

2.3.2 Forest Classifications Methods

There are different forest classification methods. Sebsebe and Edwards (2006) identify vegetation cover types as afroalpine and sub-afroalpine, dry evergreen montane forests and grassland complex, moist evergreen montane forests, evergreen scrub, Combretum-terminalia woodland and savannah, Acacia-commiphora woodland, lowland semi–evergreen forest, desert and semidesert scrubland. FAO (2000) identifies forest types as shrubland, grassland, savannah, deciduous broadleaf forests, deciduous needle leaf forests, evergreen broadleaf forests, evergreen needle leaf forests, and mixed forests. EFAP (1994b) broadly classify forest types as: natural high forest (both disturbed and undisturbed), lowland woodlands, bushlands, shrublands, wooded grasslands, plantations, and trees around farms. In this study, forest cover types were classified as natural dense forest, dense woodland, open woodland, dense bushland, open bushland, riverine, and plantation forests. This classification is based on previous classifications like EFAP (1994a, b) and WBISPP (2002). Moreover, expert knowledge, the existing forest situation of the region, and work easiness were taken into account. Each classification type is described as follows.

Fig. 2.6 Sample natural dense forests in the South Gonder, North Gonder, Awi, and East Gojam zones (*Photo* by Mulatie Mekonnen, December, 2011)

2.3.2.1 Natural Dense Forest

Natural dense forest is a type of forest cover in which the forest comprises of diverse tree and shrub species with full canopy cover (greater than 80 % canopy cover). Tree height of the dense forest is from 5 to 12 m and higher. Such forest types are observed in the priority and protected state forests, parks, churches, and the riparian forests. The species composition of this forest type is high and rich. Figure 2.6 shows some of such natural forest in the region.

2.3.2.2 Woodlands (Dense and Open Woodland)

The woodlands occupy more areas in the lowland areas of the elevated plains and plateau-escarpments between altitudes of 500 and 1900 m and correspond to a wide range of ecological conditions ranging from the semiarid to humid. The woodlands are characterized by an upper story of 5–12 m with high trees forming a somewhat closed canopy. However, it is sparse enough to let sufficient light penetrate to the dense thicket-like lower story of 1–3 m high shrubs. Open woodlands are lands covered with mainly sparsely distributed tree/shrub species and grasses with 20–50 % tree cover, while dense woodlands are woodlands that have relatively

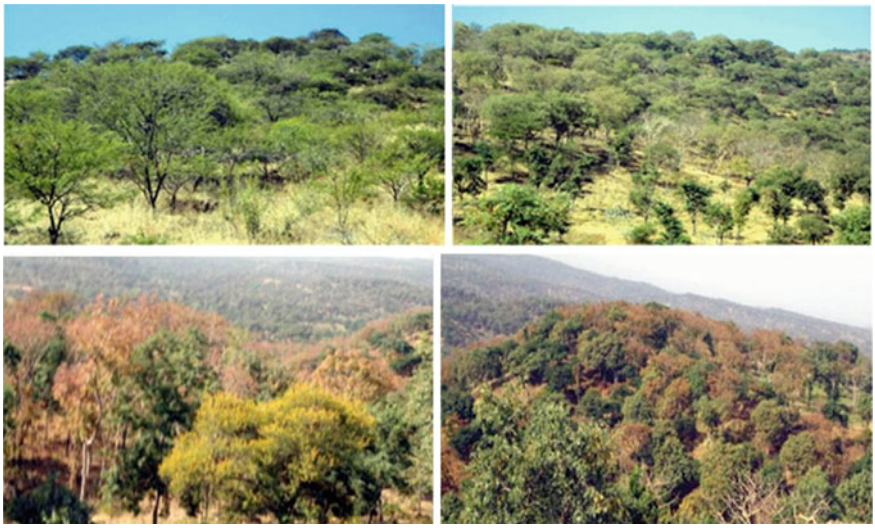

Fig. 2.7 Sample dense woodland in the North Gonder zone of Amhara region (*Photo* by Mulatie Mekonnen, December, 2011)

Fig. 2.8 Sample open woodland in the North Gonder zone of Amhara region (*Photo* by Mekonnen, December, 2011)

closely populated trees/shrubs from 50 to 80 % tree cover. Figures 2.7 and 2.8 show dense and open woodlands observed and taken at the ground, respectively.

2.3.2.3 Bushlands/Shrublands

Dense and Open Bushlands: Bushland/shrublands is a land on which there is vegetation which is either a remnant of the natural forest or altered that is still representative of the structure and floristic of the natural forest. Bushlands are lands covered with bushy type plant species and a woody cover of more than 20 %. It can be classified as dense (Fig. 2.9) and open (Fig. 2.10) based on the closeness of the

Fig. 2.9 Sample dense bushland in the North and South Gonder Zones of Amhara region (*Photo* by Mulatie Mekonnen, December, 2011)

Fig. 2.10 Sample open bushland in Waghimra zone of the Amhara region (*Photo* by Mulatie Mekonnen, December, 2011)

bushes. The canopy cover of the dense bushlands is more than 50 % and open bushlands are from 20 to 50 %.

2.3.2.4 Riverine or Riparian Forest

Riverine or riparian forests are located along sides of rivers and are part of a highly integrated system that includes the stream channel (Markm and Hunter 2000). In the study area, only a small area of most landscapes is occupied by riverine forests (Fig. 2.11) while its environmental contribution is profound.

2.3.2.5 Plantation Forest

A plantation is regularly harvested planted trees (Fig. 2.12). Plantation forests that are developed by different programs and individuals fulfill the gap between demand and supply of wood resources. Plantation forests have a wide agro-ecological

Fig. 2.11 Sample riverine forests in West Gojam, North Gonder and Awi zones of Amhara region (*Photo* by Mulatie Mekonnen, December, 2012)

Fig. 2.12 Sample plantation forest in West Gojam and North Shewa zones of the Amhara region (*Photo* by Mulatie Mekonnen, December, 2011)

coverage from mid to highland areas and consist mainly of Eucalyptus spps., *C. lusitanica,* and Acacia *decurrence*. These species have extraordinary quick growth rate where the indigenous species take a longer time to mature. This factor helped the spread over a large area through private initiatives as well as communities. At first, the plantations were limited to the surroundings of towns. But now, it is widely expanded to the rural areas where the demand for wood resource has increased at an alarming rate. Moreover, it is becoming a main source of income as cash forest.

Plantation forests are mainly found in Awi, North Shewa, South Gonder, South Wollo, East and West Gojam zones. These plantation forests range from large scale to woodlots and homesteads as clearly seen on the field and from satellite imagery. Sometimes, plantations might be mixed with the naturally grown species. In such cases, if the forests are dominated by the naturally grown species, they are considered as natural forests. But, if the planted species coverage is more than the naturally grown forest species, it is considered as plantation forest.

2.4 Results and Discussions

2.4.1 Results

Based on the collected data and field observation, the forest cover of the region is identified and quantified through screening and digitizing from SPOT satellite imagery. As a result, forest distribution map is prepared (Fig. 2.13). Most of the forest covers were found along the lowland belt of Mirab Gojam, Awi, and Semen Gonder zones bordering the neighboring country of Sudan and Tigray and Benishangul-Gumz regions. The total forest covers of the region 1,288,383 ha or 12,884 km^2 is about 8.2 % of the total land area (Table 2.1). Including bushlands it is about 2,178,295 ha or 21,783 km^2, which is about 13.85 %. Woodlands, natural dense forest, riverine forest, bushlands, and plantations coverage is shown in Table 2.1.

Each forest cover type including bushlands is described in detail in Tables 2.2 and 2.3. Accordingly, the dominant cover is bushlands that cover 889,912 ha, followed by woodlands and natural dense forest, which covers 740,808 and 463,950 ha, respectively. The riverine forest, which is part of natural forest, covers about 20,653 ha. Plantation forest has 62,973 ha coverage in the region.

As indicated in Table 2.3, North Gonder zone has the largest forest cover, about 23.96 %. Awi zone (8.86 %) is the second zone of the region with forest resources. North Shewa, West Gojam, Awi, South Gonder, and East Gojam have good coverage of plantation forest that could serve as a good example for other zones of the region. Awi zone is the best example for Acacia *decurrence* coverage, which serves as an important income source through charcoal production in addition to forest ecology.

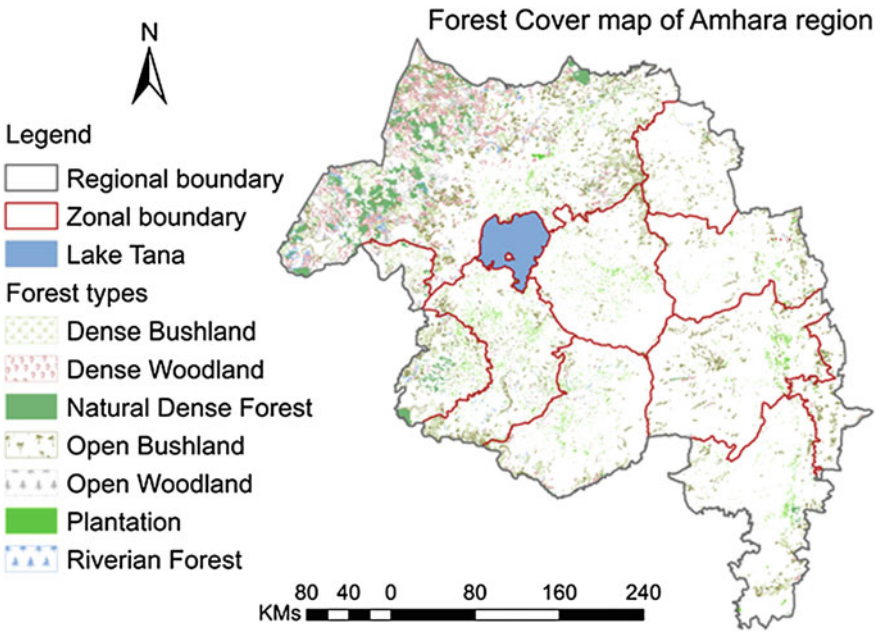

Fig. 2.13 Forest cover distribution map of the Amhara region

Table 2.1 Forest types and area coverage in the Amhara region (in ha)

No.	Forest type	Area (ha)	Forest cover (%)
1	Woodlands	740,808	4.71
2	Natural dense forest	463,950	2.95
3	Plantation	62,973	0.40
4	Riverine forest	20,652	0.13
	Sum	1,288,383	

Table 2.2 Amhara region forest cover by forest type (in ha)

No.	Forest type	Area (ha)	Cover (%)
1	Dense woodland	415,380	2.64
2	Natural dense forest	463,950	2.95
3	Open woodland	325,428	2.07
4	Riverian forest	20,653	0.13
5	Dense bushland	482,643	3.07
6	Open bushland	407,269	2.59
7	Plantation	62,973	0.40
	Sum	2,178,295	13.85

Even if the different agroclimatic zones of the region create a good opportunity for incense and bamboo resources development, man-made factors are affecting the resources tremendously. Severe degradation of lowland bamboo is observed in the

Table 2.3 Percentage of forest cover in the Amhara region by zone

Zone/forest type	Natural forest	Woodlands	Plantation	Riverine	Sum
Awi	5.53	2.76	0.49	0.08	8.86
N/Gonder	8.49	14.83	0.24	0.4	23.96
N/Shewa	0.35	0.76	0.62	0.003	1.73
W/Gojam	0.71	0.72	0.57	0.05	2.05
E/Gojam	0.87	0.95	0.36	0.02	2.2
S/Gonder	0.19	0.15	0.38	0.003	0.73
Waghimra	0.12	0.29	0.08	0.004	0.49
N/Wollo	0.21	0.49	0.46	0.02	1.18
S/Wollo	0.13	0.25	0.7	0.02	1.1
Oromia	–	0.63	0.16	0.03	0.82

Excluding bushlands

lowland parts of North Gonder, Awi, and West Gojam zones although different studies report availability in these areas. In this study, attempt was made to quantify and map the incense and bamboo resources of the region, but satellite imagery resolution was low. Therefore, further studies shall be conducted using high resolution imagery which can distinguish species clearly.

2.4.2 Discussions

GIS and satellite image-based forest resource data lacks in the Amhara region in particular and in Ethiopia in general. Therefore, it is difficult to provide adequate discussion of the results. FAO (2010) puts Ethiopia among the countries of the world with forest cover of 10–30 %. This chapter indicates that Ethiopia's forest cover (FAO definition) is 12.2 million ha (11 %). It also further indicates that the forest cover shows a decline from 15.11 million ha in 1990 to 12.2 million ha in 2010, during which 2.65 % of the forest cover was deforested. In this study the forest cover of Amhara region is about 8.2 % (4.71, 2.95, 0.4, and 0.13 % for woodlands, natural dense forest, plantation, and riverine forests, respectively) from the total land area of the region. Including bushlands (5.66 %), it is about 13.85 %.

2.5 Conclusions, Limitations, and Recommendations

2.5.1 Conclusions

The forest cover of Amhara Region is 1,288,383 ha (12,884 km^2), that is, about 8.2 % of the total land area of the region with woodlands (4.71 %), natural dense forest (2.95 %), plantation forest (0.4 %), and ravine forest (0.13 %). Including

bushlands (5.66 %), the forest cover is about 13.85 %. Natural forest cover is better in the lowland parts of the region bordering Benishangul and Tigray regions and the neighboring country, Sudan. This forest cover can contribute to slow down the rapidly expanding desertification south of the Sahara desert. The highland parts of the region have little natural forest cover, instead there is better coverage of man-made forest plantation.

Area closures are playing an important role in increasing the bushland coverage of the region; North Wollo, South Wollo, and Oromia zones are the best examples. North Gonder Zone has a very good incense resource. Quara, Metema, West Armacho, Tegede, Adiarkay, East Belesa, and Tach Armachiho are incense potential woredas of the zone. Districts like Jawi from Awi zone, Shindi from West Gojam, and Ebinat from South Gonder also have good incense potential. Awi, West Gojam, and South Gonder zones have better highland bamboo resource in the region.

Inaccessibility and hot temperature played a vital role in conserving the remaining forest resources of the region. Satellite imagery, GIS, and GPS technologies are found to be essential tools in identifying, quantifying, and mapping forest resources. Such technologies are vitally important to reach and assess resources otherwise inaccessible and remote.

2.5.2 Limitations of the Study

Since the satellite imagery used in this study was taken in 2008, recent plantations, closed area regenerations, and deforestation are not included. Lack of studies on the forest resources of the region limited reference resources. Agroforestry practices were not considered or included.

2.5.3 Recommendations

Further forest species inventory and proper management are vitally important. Higher resolution satellite imagery taken at different times, that is, satellite image taken in November for the western and northern lowlands, and in January for other parts of the region, should be used for further study. Investors are creating a bad shadow on the natural forest cover, in the name of agriculture and incense investments. Resettlements are also causing deforestation. Therefore, care should be taken.

The forest management guidelines formulated by the ANRS, BOA should be strengthened and implemented to conserve forest resources of the region, particularly the lowland forests bordering the Benishangul and Tigray regions and the neighboring country, Sudan. Forest cover can contribute to slow down the rapidly expanding desertification south of the Sahara desert. Promoting agricultural practices like honey bee, controlled livestock rearing, ecotourism, and others is more preferred for sustainable use of the forest resource of the region.

Detail studies should be carried out on farm forestry or agroforestry resource using higher resolution and better coverage satellite imagery. Forest density, diversity, and population can be further areas of study. Regional forest resource inventory and database are vital for forest resource management.

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