

# Evolution of the forest cover in Armenia

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## SUMMARY

This paper illustrates the geographical extent of the Armenian forests at five points in time, from the year 4,000 B.C. to the present. For each period the social and economic context that is most relevant to the use and conservation of the forests is presented. An extensive literature search for the most reliable geological, archaeological, and bio-geographical records was conducted to provide an estimate of the extent of the forest cover in ancient times. According to the estimates produced, and the National Forest Inventories during the Soviet period, the forest cover has decreased from covering approximately 35% of Armenia during the first three millennia B.C., to 8.1% during the 1950s, 11.2% during the 1980s, to 7-8% today. The degree of deforestation that Armenia has suffered and the likelihood of losing the remaining highly fragmented forest areas in the coming years is highlighted.

Keywords: Armenia, forest cover, deforestation, GIS, forest inventories.

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## INTRODUCTION

The uses of the goods and services provided by the Armenian forests have evolved through time in response to changes in population, culture, politics, and economics. The last few decades have seen a reduction of the extent and quality of the forest cover in Armenia. Given the current economic, social and political conditions in the country this decline is likely to continue and probably accelerate. This poses a serious threat to Armenia's long-term sustainable development. To reverse this trend it is important to revive Armenian forestry culture and educate a new generation of stakeholders, scientists, resource managers, and politicians (in Armenia and abroad) about the characteristics and extent of the Armenian forests.

Since the dissolution of the United Socialist Soviet Republics (USSR) in 1991, Armenia has been working on developing its human, material and knowledge infrastructure for the management of its natural resources. During the Soviet period most of the planning and decision-making regarding these activities took place at a centralized level and little local infrastructure was developed. There are different data and articles on forest and land-use changes in Armenia but they are very scattered and never have been compiled and interpreted. Furthermore, there are no explicit cartographic representations of the historical extent of the forest cover in the country that are reliable and based on the best information from literature,

archaeological, and bio-geographical sources.

The purpose of this article is to present in a consistent format the evolution of the extent of the forest cover in the Republic of Armenia from approximately the year 4000 B.C. to the present making use of the most reliable direct and indirect sources of information for each of the historical periods considered. A set of consistent cartographic products were created using Geographic Information Systems (GIS) to illustrate the geographical extent of the forest cover. For each historical period considered, the most relevant social, economic, and environmental conditions that affected the use of the forests and their conservation are described. Our aim is to contribute to the knowledge base of Armenian natural resources for the benefit of the international community and the Armenian people. The remainder of the article is organized as follows: the second section presents a brief overview of the history, the physical and human geography, and the forest cover characteristics in Armenia, following sections present the most relevant social and economic conditions for each of the historical periods considered, and a map of the estimated forest cover extent based on the most reliable sources of information for the period, finally a discussion and a series of conclusions and recommendations are presented. All the maps used in this paper are in Universal Transverse Mercator (UTM) projection NAD 83 zone 38.

**BRIEF OVERVIEW OF ARMENIAN HISTORY, HUMAN AND PHYSICAL GEOGRAPHY, AND FOREST COVER CHARACTERISTICS**

The Republic of Armenia is located in southwest Asia east of Turkey (see Figure 1). Over the centuries Armenia enjoyed brief periods of autonomy and came under the sway of various empires including the Roman, Byzantine, Arab, Persian, and Ottoman. It was incorporated into Russia in 1828 and into the United Soviet Socialist Republics (USSR) in 1920. Independence was achieved in 1991. The early years as an independent nation were marked by war and economic hardships. From 1988 to 1994 Armenia was involved in an armed conflict with Azerbaijan over Nagorno-Karabakh a region assigned to Soviet Azerbaijan in the 1920s by the Soviet leadership. In May 1994 a cease-fire took hold, but by then the economies and environment in both countries had been severely damaged (CIA 2005).

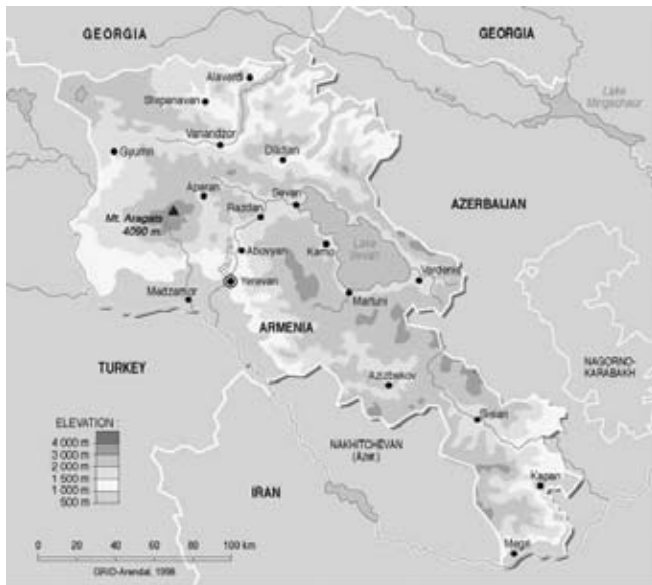
The country has a total area of 29 800 km<sup>2</sup> (similar to the size of Belgium). The lowest elevation is 400m along the Debed River (northern Armenia), and the highest is 4,090 m at the top of the mountain Aragats (central Armenia see Figures 1 and 2). About half of the area of the country has elevations of 2000 m or higher and only 3% of the country lies below 650m (see Figure 2). The country faces several environmental problems and challenges including: a) soil erosion (it is estimated that two thirds of the country suffers from heavy to medium erosion processes (Hayrapetyan 2000)) and pollution from toxic chemicals, b) water shortage (in particular for irrigation) and water pollution, c) the pollution and draining of Sevana Lich (Lake Sevan) from its use for hydropower generation and irrigation, which is a serious threat to drinking water supplies, d) increased deforestation since the 1990s when citizens scavenged for firewood because of an energy crisis, e) biodiversity loss (CIA 2005).

FIGURE 1 *Map of Armenia*



Source: United Nations, Department of Peace Keeping Operations, 2004

FIGURE 2 Topography of Armenia



The country is a republic with 11 provinces. The current population is 3,326,448 (estimate for 2003 based on the first Armenian census of 2001), which currently is decreasing at a rate of 0.07% due mostly to emigration to other countries. Two thirds of the total population is concentrated in the capital Yerevan (1 091 230 people) and in the Ararat plain region. Over 98% of the population is over 15 and can read and write.

Armenia is situated in a dry subtropical climatic zone. Annual precipitation ranges from 250-300 mm in the Ararat plain to 1 000 millimetres on Mount Aragats (see Figure 1 and Figure 2). The country's complex topography creates several microclimates and these give rise to a large diversity of vegetation types from a semi-desert in Ararat plain to sub-alpine and alpine zones at the top of Mount Aragats (see Figure 1). There are about 3 600 different species of high vascular plants in the country (Grigoryan 1979, Vardanyan 2003).

The following terms are used in this paper:

- Forest cover to denote a land cover dominated by tree species.
- Deforestation to indicate the long-term or permanent removal of the forest cover (totally or below 10% of the ground cover) and conversion to a non-forested land use (Lund 1999).
- Degradation to indicate a reduction in the natural or desirable characteristics of a forest (e.g. age classes structure, density, or standing stock genetic quality).

The Armenian forest cover is rich in biodiversity, it contains 110 tree and 152 shrub species (Abrahamyan 1960, Grigoryan 1979). The dominant tree species are broadleaf deciduous trees. Today a mix of oak (*Quercus spp.*), beech (*Fagus orientalis*) and hornbeam (*Carpinus betulus*) compose 81.3% of the forest cover. Pines (*Pinus*

*spp.*) mostly in plantations represent 5.3%, juniper (*Juniperus spp.*) 2.5%, and other broadleaf deciduous trees (mainly hornbeam coppice *Capinus caucasica*, lime *Tilia cordata*, ash *Fraxinus exelsior*, and maple *Acer spp.*) 10.9% of the forest cover.

The north-eastern and south-eastern parts of the country and the eastern bank of Lake Sevan have the most favourable climatic and environmental conditions for the growth of forests. Today 62% of the forest cover is found in the northeast, 36% in the southeast, and only 2% in the central region of the country.

Several studies have, directly or indirectly, addressed forest cover and land-use changes in Armenia, however these studies: a) are very scattered, b) are found in publications of very limited access and distribution, c) are published in Armenian or Russian which limits access to the international community, d) do not have an explicit geographical representation or have used different geographical reference systems making them incompatible for geographical extent comparisons and visualization.

In the work presented in this paper we have aimed to: a) consolidate the most reliable information regarding changes in forest cover over the longest historical span possible, b) create an explicit geographical representation of the forest cover in ancient times using the results of geological, archaeological, and bio-geographical studies, c) create, using GIS, a digital set of geographical layers representing the national forest cover at different points in time that is consistent and comparable, d) make this information accessible to the international community, and d) provide the basis for the creation of a national digital geographical atlas of the Armenian forest resources.

After carrying out an extensive search for direct and indirect sources of information regarding the extent of the forest cover in Armenia, we decided to create or compile an explicit geographic representation of the forest cover for the following historical periods: a) From the Bronze Age (4000 to 3000 B.C.) to the year 1 B.C., b) The XVII and XVIII centuries, c) the National Forest Inventory of 1966-1968, d) the last Soviet period National Forest Inventory in 1986-1989, and e) an estimation of forest cover in the year 2000.

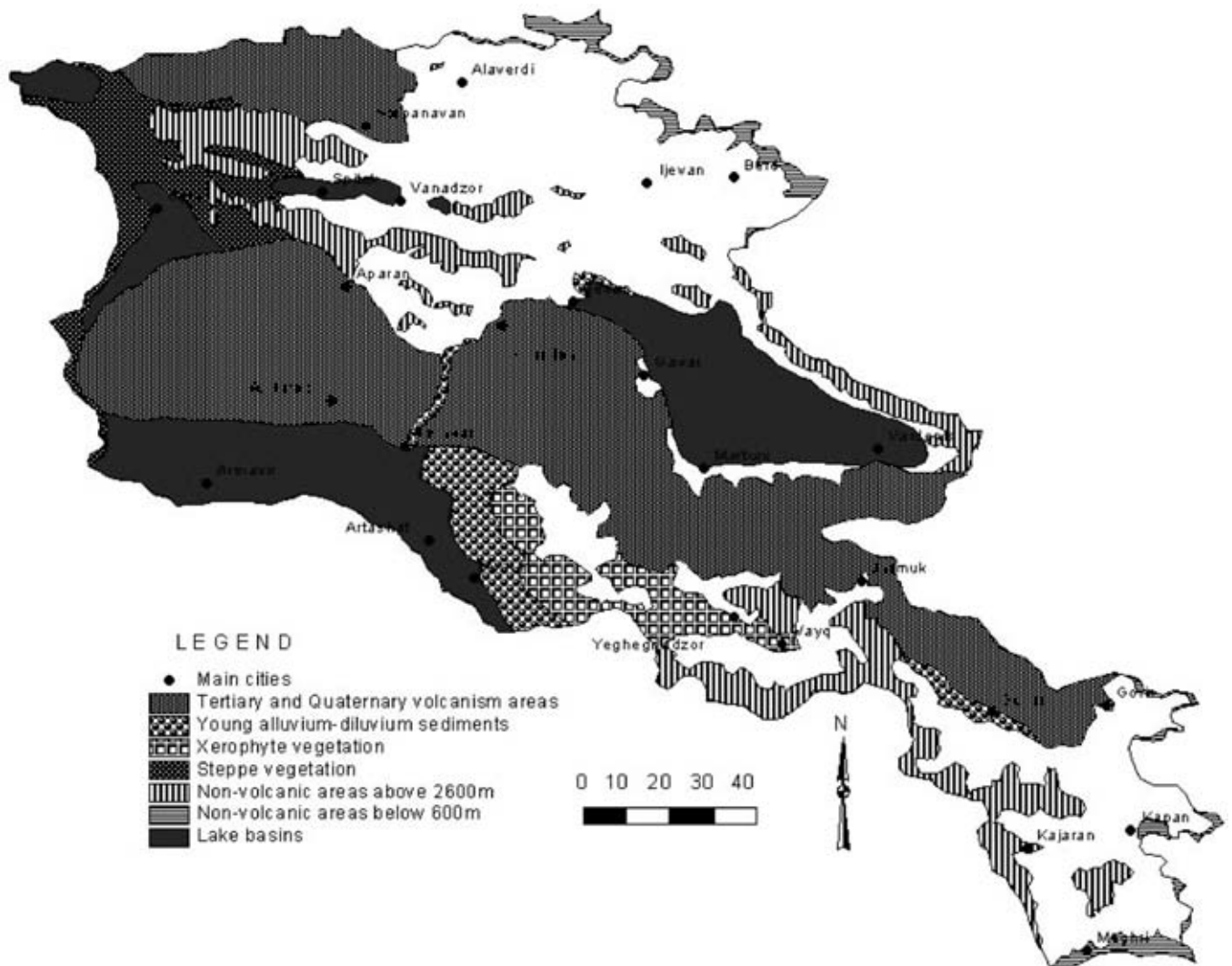
The scale of the maps presented here is such that the extent of the forest cover can not be mapped down to the hectare resolution as it is reported in the body of the text and Tables 2 and 3. Also, as it will be described later, for different reasons for each of the historical periods considered there is a high degree of uncertainty regarding: the exact extent of the forest cover (less so for the Soviet period forest inventories), and the estimations of some of the most important forest parameters (such as mean annual growth). We have reported the areas and percentage figures according to the sources where they were found. However for the reasons mentioned, it is recommended that the reader consider that the forest cover areas and percentages reported in the text and Tables are reliable to the nearest thousand hectares and to the nearest one percent.

Several studies suggest that large areas in the country have not supported forests since the tertiary period (see Figure 3). Takhtajyan (1937), Grossheim (1948), and Yaroshenko (1956) suggest that many vegetation types, particularly mountain xerophytes (e.g. pistachio *Pistacia mutica*, almond *Amygdalus fenzlianum*, and rose *Rosa spp.*) in south-western Armenia and the neighbouring Nakhichevan area (in the north of the Republic of Azerbaijan see Figure 1), were formed in the second half of the tertiary period and have kept their original forms to this day. The same is true for xerophytes that evolved since the beginning of the quaternary era in the areas around the cities of Aragats, Aparan, Qanaker, and Nork (the last two cities are suburbs of the capital Yerevan) in central Armenia (see Figure 1), and in the Erablur and Sisian plateaus (between the cities of Sisian y Goris see Figure 1) in southern Armenia (Yaroshenko 1956). Analyses of quaternary volcanism and geological developments (Abrahamyan 1967) largely support that forests have not existed in all the above mentioned areas since the tertiary period.

FIGURE 3 Map of areas that have not supported forests since the tertiary period

ESTIMATION OF THE FOREST COVER DURING THE YEARS 4 000 TO 1 B.C.

Several archaeological studies (Lalayan 1931, Mnatsakanyan 1952, Mezhlumyan 1972) have found remnants of animals such as deer (*Cervus elaphus*), bears (*Ursus spelearctos*), wolf (*Canis lupus L.*), and foxes (*Vulpes vulpes L.*) that are strongly associated with the presence of deciduous forests on the western, north-western and south-eastern banks of Lake Sevan, and in south-western Armenia. These findings date back to the years 4 000 to 1 000 B.C. Some of these studies (Mnatsakanyan 1952) have also found bronze and wooden statues of deer and other animals that inhabit deciduous forests. Pollen analyses done in the valley of the Masrik river (south-eastern bank of Lake Sevan) (Takhtajyan 1941) and the valley of the Gavaraget river (western bank of Lake Sevan) (Sayadyan 1983) strongly support the idea that broadleaf deciduous forests once existed there. Dal (1947) found remains of deer in the Vayk and Urts mountains (next to the city of Vayk see Figure 1 and Figure 4) in south-central Armenia that date back to the year 2,000 B.C. These findings suggest that during this period there was a large broadleaf deciduous



forest in the area around the city of Vayq (see Figure 4).

Throughout Armenia there are many direct and indirect indications of human population impacts on the forests during the first millennium B.C. (Piotrovskiy and Gyuzalyan 1933, Piotrovskiy 1944, Martirosyan 1951, Martirosyan and Israelyan 1981). According to cuneiform registrations of the Urartian kings Menua, Argishti, Sarduri II, and Ursa (IX-VII centuries B.C.), and several Assyrian kings including king Khatushil (XIV-XIII centuries B.C.), the population in the Armenian highlands was occupied with horticulture, animal husbandry, and cultivation of several fruits, in particular grapes. These activities imply that forested areas needed to be cleared and forest products used for vineyard guides, construction materials and fuelwood. The practice of planting forests was highly popular during the Urartu kingdom (IX to the XVII century B.C.) (Piotrovskiy 1944, Mirimanyan 1959).

According to geological studies (Geology of Armenia SSR 1962) and paleogeographical studies (Abrahamyan 1967), forests could only exist on sedimentary rocks because neither volcanic rocks nor ancient lake or river beds could support them (see Figure 3).

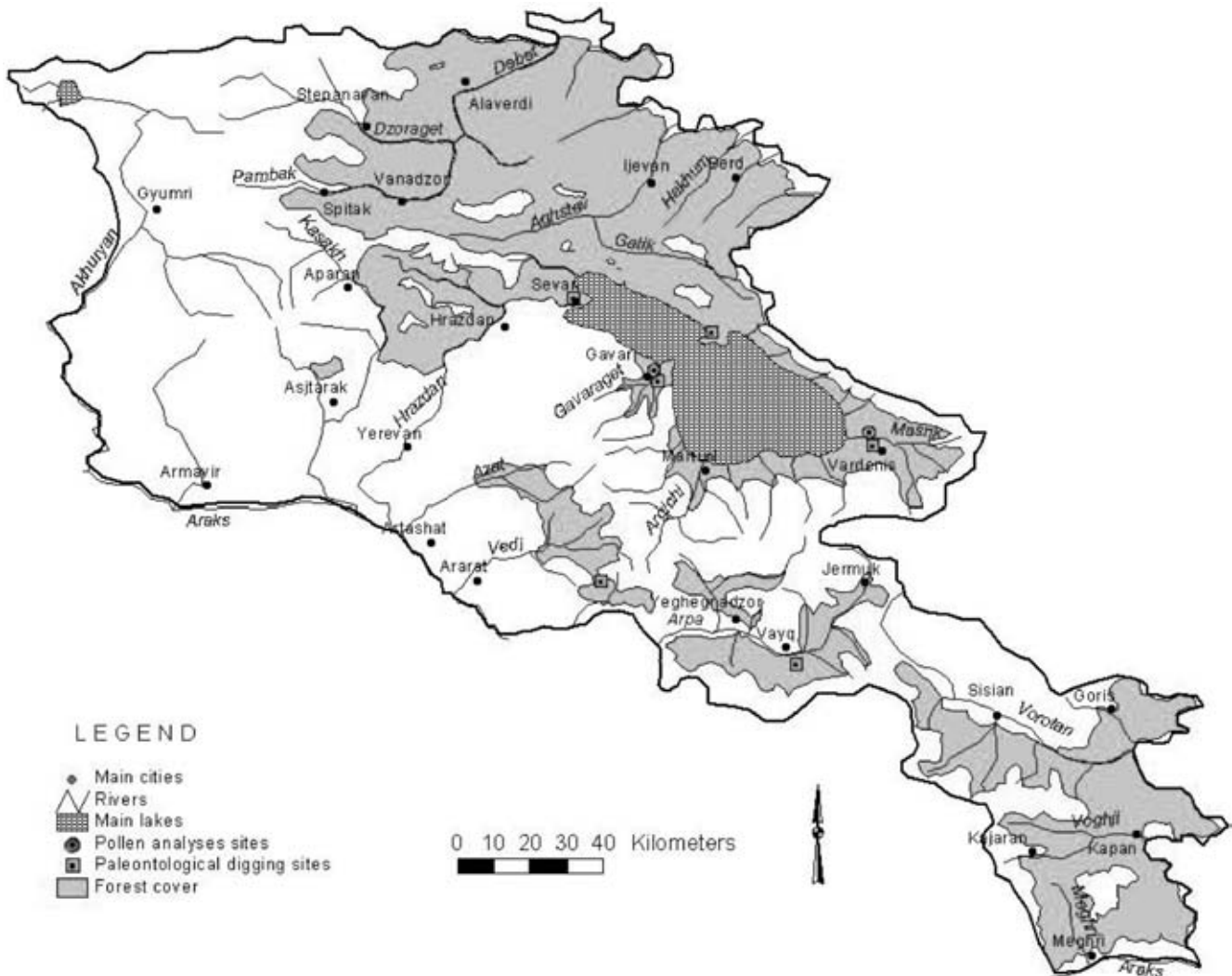
To create the map shown in Figure 4, it was necessary

to: a) delineate the areas that had not supported forests since the tertiary and quaternary periods to this day, and are covered by xerophytes vegetation as shown in Figure 3, b) delineate the mountain areas where sedimentary rocks are present, c) delineate the areas where the archaeological and bio-geographical studies suggest that forests once existed, and d) delineate the areas in the elevation range (500 to 2 700m) that according to several studies favours the existence of forests (Gulisahsvili 1955, 1958, Makhatazde 1957, Abrahamyan 1958a, 1958b). The map in Figure 4 shows the areas that could have supported forests based on these criteria. The areas identified encompass currently existing remnants of forests that have not been destroyed due to their inaccessibility. This gives us a small degree of confirmation that the areas identified represent the potential extent of the forest cover.

ESTIMATION OF THE FOREST COVER DURING THE 17<sup>th</sup> AND 18<sup>th</sup> CENTURIES A.D.

Political instability marked the social and economic scenes in Armenia from the 1<sup>st</sup> to the 18<sup>th</sup> century A.D.

FIGURE 4 Estimated forest cover during the years 4 000 to 1 B.C.



The country's independence was lost several times in frequent waves of invasions from the Roman Empire, Persia, Arabs, Mongols, and the Turk-Seljuk. These were affected the Armenian forests, for example, Arab historians (Istakhri, and Ibn Al Fakikh) from the 8<sup>th</sup> and 9<sup>th</sup> centuries noted that Arab invaders cut and exported high quality timber from Armenia. The same occurred during the Byzantine, Turk, and Persian invasions (Leo 1917).

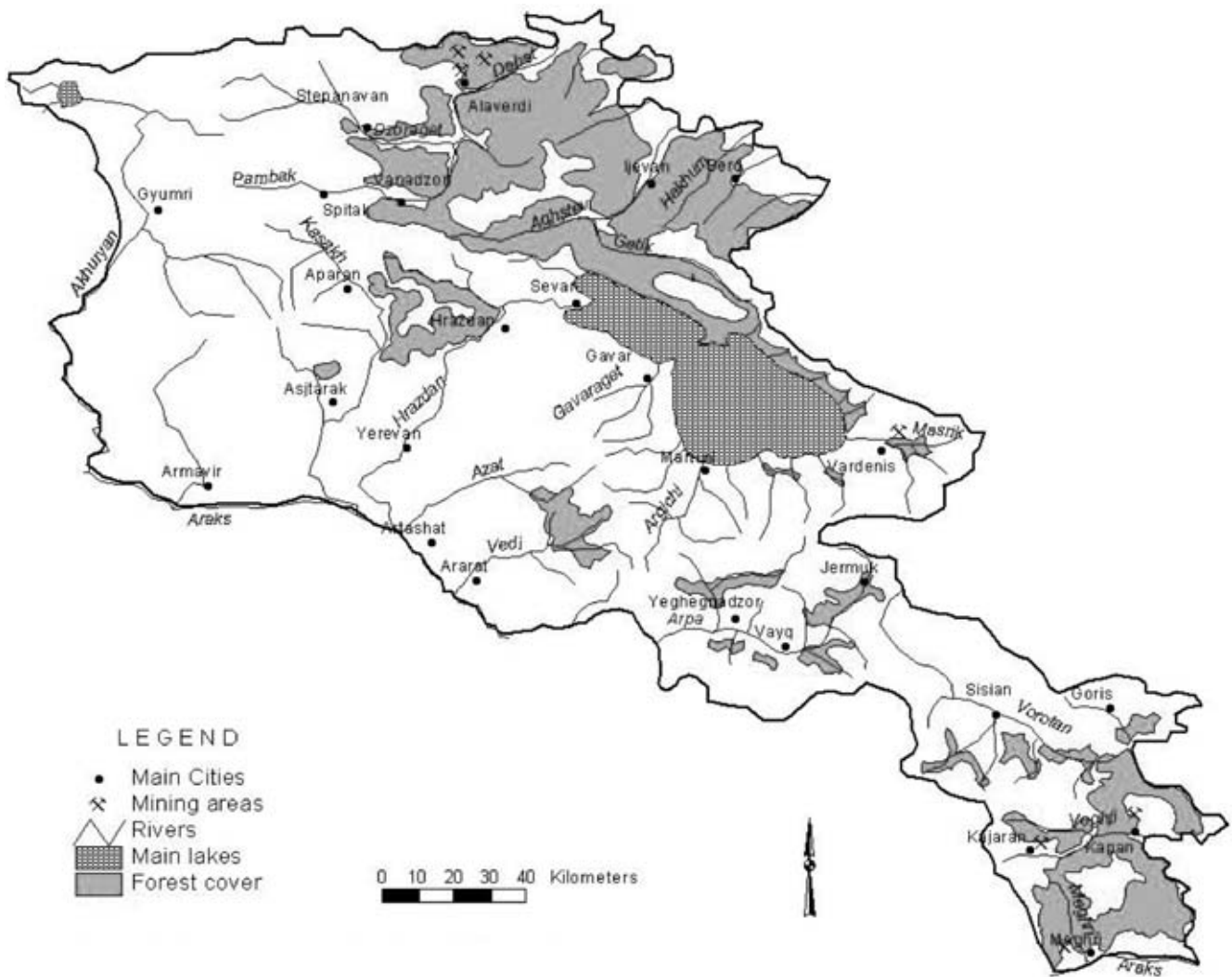
There are few records from the 1<sup>st</sup> to the 18<sup>th</sup> centuries describing the forest cover, however it is valuable to cross reference the little information there is with other sources to try to estimate the forest cover during this period. According to the 5<sup>th</sup> century Armenian historian Movses Khorenatsi (Khorenatsi 1981), the Armenian king Ervand (first century A.D.) planted a forest (known as the Tsndots Antar forest) around the ancient city of Bagaran in the Ararat plain, and another forest (Sosyac Antar forest) close to the city of Armavir. Today there are no remnants of these plantations because they were located in easily accessible areas in the middle of Ararat plain and long ago have been converted to agricultural use. In the 4<sup>th</sup> century, king Khosrov (330-339 D.C.) established a forest plantation

between the Azat and Vedi rivers in central Armenia that still exists today. In 1958, this forest (known as the Khosrov forest) became the first State Forest Reserve in Armenia.

According to the Armenian historian Leo (Leo 1917) during the 7<sup>th</sup> and 8<sup>th</sup> centuries on the southern bank of Lake Sevan there was well-developed wood handicraft production in the towns of Tsar (meaning 'tree' in Armenian) and Takhtak (meaning 'wood board' in Armenian). These towns do not exist today and their exact historical location is unknown, however the whole southern bank of Lake Sevan is currently devoid of natural forests (see Figure 6). In the medieval ages large areas of forests in Armenia were transformed into agricultural land at the lower elevations and into grasslands for cattle and sheep grazing at higher elevations (Sayadyan 1997). Before 1828, forests in Armenia were in the hands of small private owners. In 1828, when Armenia joined the Russian Empire, the majority of the forest areas were included under the Tsar Forest Department. It is interesting to note that the majority of the forests in Armenia belonged to the state even before the Soviet period.

Several Armenian and Russian botanists and foresters

FIGURE 5 Estimated forest cover distribution during the 17<sup>th</sup> and 18<sup>th</sup> centuries



from the 1930s (Kuznetsov 1900, 1909, 1915, Kara-Murza 1929, 1931, Shelkovnikov 1929, Zedelmeyer 1930, Maghakyan 1941, Takhtajyan 1941, Yaroshenko 1941, 1956) and 1950s (Dal 1947, Grossheim 1948, Gulisashvili 1955, 1958, Makhatadze 1957, Abrahamyan 1958a, 1958b, Mirimanyan 1959) estimated that the forest cover in Armenia 200-300 years ago was probably twice as much as the one existing during the first part of the 20<sup>th</sup> century. Considering that according to the 1950s forest data inventory the natural forest cover in Armenia was approximately 9% of the total area of the country, we can estimate that forests covered approximately 18% of Armenia during the 17<sup>th</sup> and 18<sup>th</sup> centuries (see Table 3). Also, the vegetation map of German botanist Koch (Koch 1850) from the middle of 19<sup>th</sup> century serves as further confirmation of this estimation.

During the 18<sup>th</sup> to the 20<sup>th</sup> century the human impact on the forests changed in nature from mainly deforestation due to agriculture in the lower elevations and animal husbandry in the high mountain meadows, to over exploitation for industrial uses. During the period 1763 to 1917 75 000 tonnes of copper were processed in 20 small metallurgical factories located across the country (8 in northern and 12 in southern Armenia see Figure 5) (Melkonyan 1955). According to this reference, annually 40 to 42 thousand m<sup>3</sup> of wood were used for preliminary 'roasting' of raw copper ore, 2 333 tonnes of charcoal were used for further 'roasting', 2000 tonnes of charcoal were used for fusing, and 333 tonnes of charcoal were used for the clean up (Melkonyan 1955). If we accept the conversion of 7 m<sup>3</sup> of wood for 1 tonne of charcoal (which is the case for Armenian hardwood forests), then the total annual wood consumption for copper production was on average 73,000 to 75,000 m<sup>3</sup> per year for the mentioned period (40-42 thousand m<sup>3</sup> plus 32,666 m<sup>3</sup> to produce 4,666 tonnes of charcoal). Melkonyan (1955) also mentions that 24 tonnes of charcoal were required to produce 1 tonne of red copper. Again, if we accept the above-mentioned conversion rate of wood to charcoal, this production would require an average of 81 818 m<sup>3</sup> of wood per year over the indicated 154-years period. Another example of the intense use of the forests is the report by Shopen (1852) who notes that in the second half of 19<sup>th</sup> century only the small city of Nor Bayazet (currently named Gavar - see Figure 5) located on western bank of Lake Sevan extracted 2,000 m<sup>3</sup> of timber for fuelwood from the eastern bank of the lake.

All the previously referenced information does not have an explicit geographical representation. To create the forest cover map in Figure 4 we used the results of the studies carried out by the Armenian and Russian botanists and foresters from the 1930s and 1950s cited above, and later studies by Yaroshenko (1962), Abrahamyan (1967), Dolukhanov (1976), Grigoryan (1979), Khurshudyan *et al.* (1987), Kurshudyan (1999a), Khurshudyan (1999b), and Vardanyan (2003). These studies estimated that the altitudinal distribution of forest cover in Armenia during the 17<sup>th</sup> and 18<sup>th</sup> centuries retreated in the lower elevations from 500 meters to 700 meters and in the higher elevations from 2,700 meters to 2,500 meters above

sea level. Using this information we proceeded to reduce the forested areas in Figure 4 to the elevation range 700 to 2,500 meters resulting in the map shown in Figure 4.

## THE SOVIET PERIOD NATIONAL FOREST INVENTORIES AND FOREST MANAGEMENT PRACTICES IN ARMENIA

The copper mining industry was established in the late 1800s by French missionaries in accordance with a license agreement with the Tsar government. The first visual forest inventory activities were conducted in 1887 by these missionaries in the most northern and south-eastern parts of the country around the copper mines in these regions (see Figure 5). The purpose of the inventories was to estimate the volume of timber that could be converted to charcoal for the copper industry and the availability of timber to support the construction of the associated railway.

Forest inventory and management plans during the Soviet period were centrally prepared (usually in Moscow or at a regional forestry office such as in Georgia) far away from the Armenian forests (Thuresson *et al.* 1999, Thuresson 2003). Forest inventories at the national level took place at ten-year intervals during 1956-1958, 1966-1968, 1978-1983 and 1986-1989. Soviet forest inventories were characterized by the use of 'visual assessments'. Aerial photography and field visits were used to determine the extent of the forest cover and to classify it into homogeneous forest stands. Then experienced foresters would walk through the forest stands and visually estimate key forest parameters such as age, height, diameter, and species composition. There was no use of sampling methods based on inventory sites or statistical methods to extrapolate the sampled tree's characteristics to homogenous forests stands. Obviously, this approach was highly subjective and made the estimation of key forest stand parameters (such as the mean annual growth) a guessing game. It has been proven that these practices grossly underestimated the mean annual growth of the Armenian forests (Thuresson *et al.* 1999). This underestimation was used as a base to determine allowable cuts and design management regimes. The resulting poor management decisions from the 1930s

TABLE 1 *Tree age categories distribution for Armenian forests during the 1960's and 1980's*

Age Class (years)	% of the total forest cover	
	1960s	1980s
Young stands (1-40)	6.5	9.3
Middle age stands (40-100)	46.5	51.4
Mature stands (100-140)	21.1	17.6
Over mature stands (More than 140)	25.9	21.7
Total	100	100

to the 1950s, combined with protectionist policies, led to the creation of over-mature forests (see age classes distribution in Table 1) with low densities and low annual growths.

#### FOREST COVER ACCORDING TO THE 1966-1968 NATIONAL FOREST INVENTORY

##### Brief economic and social context during the 1960s and 1970s

The industrial exploitation of the Armenian forests clearly started when the country joined the Russian empire in 1828. After the establishment of the Soviet authority in Armenia in 1920 the country switched from an extensive agrarian economy to a highly industrialized economy with great impact on its natural resources and environment. Most of the industrial and agricultural infrastructure of Soviet Armenia was established during the 1930s to the 1950s. The growth of the copper-molybdenum mine industry demanded large amounts of timber that was extracted from the forests starting in the areas next to the industrial cities such as Kapan, Kajaran, Agarak, Alaverdy, Akhtala and Shamlugh (these last two cities are suburbs of the Alaverdy city see Figure 5). The copper industry and later the very large chemical industry established during the Soviet period created a serious air pollution problem that affected the forests health in northern and southern Armenia. During the 1960s and 1970s many new chemical, machinery and light industry factories were built in the capital Yerevan and the city of Vanadzor among others.

The creation of large collective agricultural units (sovkhoz and kolkhoz units) dramatically increased the impact on soil and water resources. Improper agricultural practices caused erosion and degradation of large areas (Hayrapetyan 1976, 1979). The area of irrigated and mechanically cultivated lands increased each year during the 1960's and 1970's.

In parallel to the industrialization and intensive

agriculture development, the population and number of settlements increased drastically. At the beginning of Soviet period (1920) the total population in Armenia was 720 000 people. By the 1960s it was close to two million due to immigration and the high population growth rate after World War II. The new settlements and their associated roads networks had an impact on forest cover particularly at lower elevations. Extensive animal husbandry (sheep, goats, and cattle) in the higher elevations impacted the areas next to sub-alpine and alpine meadows pastures.

Armenia has never had a large forest industry. The main forest industries are small particle board and furniture factories and wood handicrafts. During the 1960s 60 000 to 70 000 m<sup>3</sup> per year of timber were extracted from the Armenian forests mainly as result of the removal of dead and infected trees. The particle board and furniture industries are concentrated in the capital Yerevan and the city of Ijevan in north-eastern Armenia. Starting in the 1960s timber imports from Russia grew exponentially and reached approximately 90% of the demand for forest products in Armenia.

##### Characteristics of the forest cover in Armenia during the 1960s and 1970s

According to forest inventory data from the 1960s there were a total of 253 000 hectares covered by forest. This surface represents 8.5% of the Armenia territory. It was estimated that there were 29.7 million m<sup>3</sup> of timber, and that the average timber volume per hectare was 117.4 m<sup>3</sup>. In 1966 88.34% of the total forest cover was composed of mixed oak, beech and hornbeam stands (see Table 2). Pine occupied 0.98% of the forest cover, and juniper forests occupied 1.66%. Only 0.33% of the pine forests cover was natural, the rest corresponds to different plantations established during the second half of the 20<sup>th</sup> century. During the 1960s and 1970s the forest cover was geographically distributed as follows: 28% in the northeast, 2.3% in the central region, 2.2% around Lake Sevan and 13.9% in the southeast (see Figure 6 and Table 2).

TABLE 2 *Tree species distribution 1941-1988*

Dominant tree species	1941		1956		1966		1977		1988	
	Area (hectares)	% of total forest cover	Area (hectares)	% of total forest cover	Area (hectares)	% of total forest cover	Area (hectares)	% of total forest cover	Area (hectares)	% of total forest cover
Pine	927	0.33	969	0.4	2500	0.98	1295	0.5	17700	5.3
Juniper	7862	2.77	6357	2.4	4200	1.66	12714	4.7	8400	2.5
<b>Oak</b>	80241	<b>28.21</b>	83294	<b>34.5</b>	87200	<b>34.47</b>	97852	<b>35.8</b>	120000	<b>35.9</b>
<b>Beech</b>	109201	<b>38.4</b>	85310	<b>35.7</b>	89700	<b>35.45</b>	89533	<b>32.8</b>	96600	<b>28.9</b>
<b>Hornbeam</b>	60365	<b>21.23</b>	46543	<b>19.2</b>	46600	<b>18.42</b>	50976	<b>18.6</b>	55100	<b>16.5</b>
Maple	210	0.07	2758	1.1	-	-	2533	0.9	-	-
Hornbeam(c)	9486	3.34	1026	4.1	6600	2.61	-	-	8300	2.5
Birch	769	0.27	1172	0.5	800	0.32	1957	0.7	-	-
Lime	2950	1.04	1315	0.6	1000	0.4	1415	0.5	-	-
Elm	634	0.22	1062	0.4	-	-	1949	0.7	3006.9	0.9
Ash	3069	1.08	807	0.3	-	-	2141	0.8	7350.2	2.2
Other species	8674	3.05	2040	0.8	14400	5.69	10746	4	17642.9	5.3
<b>Total</b>	<b>284379</b>	<b>100</b>	<b>241753</b>	<b>100</b>	<b>253000</b>	<b>100</b>	<b>273111</b>	<b>100</b>	<b>334100</b>	<b>100</b>

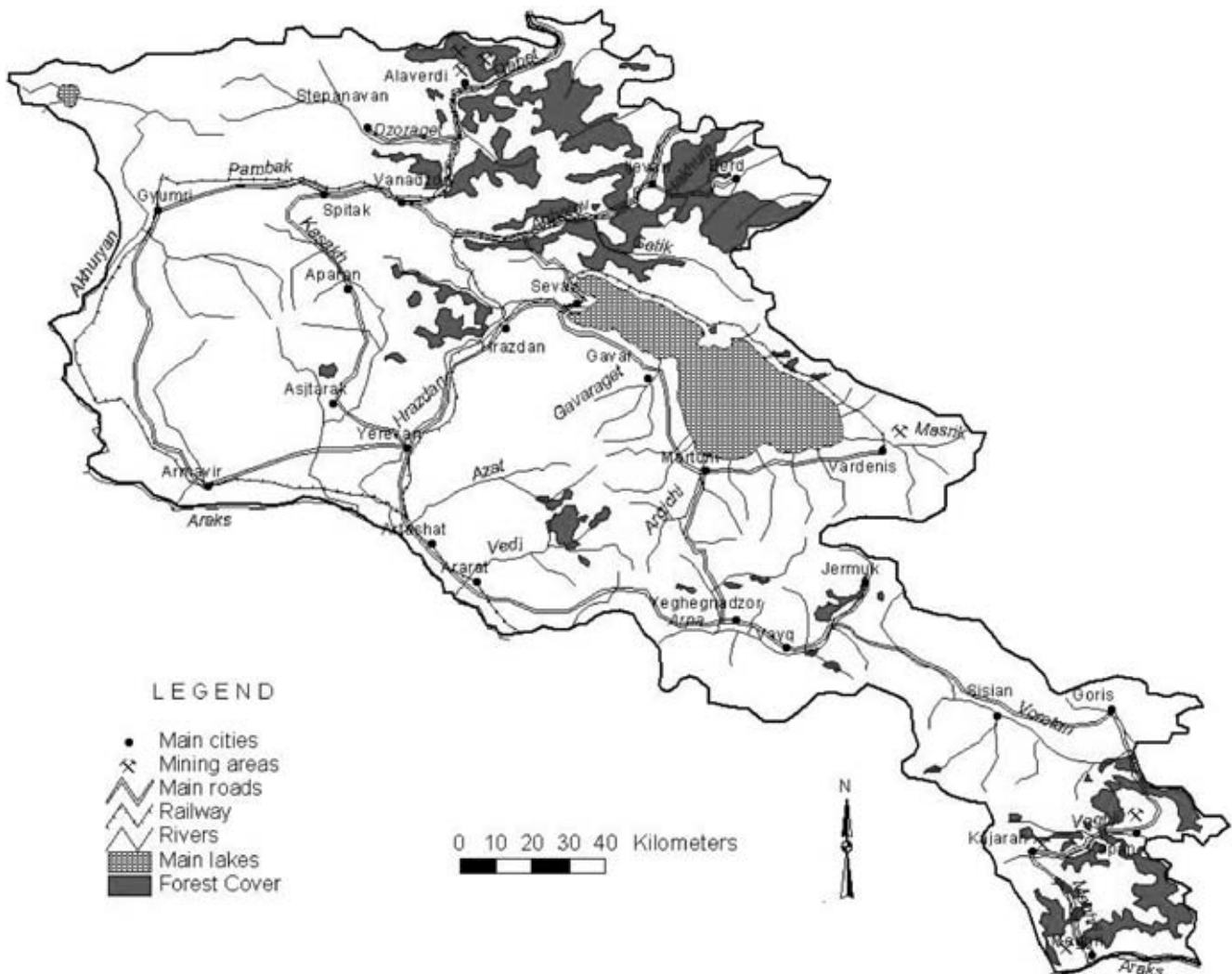
The intense deforestation processes that started during the 18<sup>th</sup> and 19<sup>th</sup> centuries continued until the 1950s. Forest inventory data show that in 1941 (Maghakyan 1941) the total forest cover was 284 379 hectares or 9.6 % of the Armenian territory (see Table 3). This amount decreased to 241 753 hectares (8.1% of the territory) by 1956 (Abrahamyan 1960). The participation of Armenia as part of the USSR in World War II and the huge industrialization and intense agricultural development in the post-war period influenced the deforestation process. Nevertheless, the 1978-1983 National Forest Inventory reports that forests covered 9.98% of the country, an increase of 1.88% from the 1956 data (see Table 3). This increase is explained by the forest plantations established from the 1950's to the 1970's mainly around Lake Sevan (17 000 hectares), and the cities of Yerevan and Vanadzor, and by the reduction of regulated and unregulated forest cuttings due to the increase of timber imports from Russia. The forest cover map shown in Figure 6 is derived from the 1966-1968 National Forest Inventory.

**FOREST COVER ACCORDING TO THE 1986-1989 NATIONAL FOREST INVENTORY**

The economic and social conditions during the 1980s mimicked closely the conditions and trends displayed during the previous two decades. There were practically no commercial forest cuts and 90% of the demand for forest products was satisfied with imports from Russia.

According to forest inventory data from the 1980s there were a total 334 100 hectares covered by forest representing 11.2% of the territory (see Figure 7 and Table 3). It was estimated that there were 41.7 million m<sup>3</sup> of timber, and that the average timber volume per hectare was 124.9 m<sup>3</sup>. This is the largest extent of the forest cover during the Soviet era. This estimation implies a 1% per decade increase in the forest cover from 1956 to 1986 (from 8.1% to 11.2% of the total territory), or 3 078 hectares per year during this period for a total of 92 347 hectares. This increase is due mainly to the forest plantations that were carried out during the 1970's and 1980's (Khurshudyan *et al.* 1987, Sayadyan and Nalbandyan 2002).

FIGURE 6 Forest cover according to the 1966-1968 National Forest Inventory



ESTIMATED NATIONAL FOREST COVER FOR THE YEAR 2000

**Brief economic and social context during the 1990s**

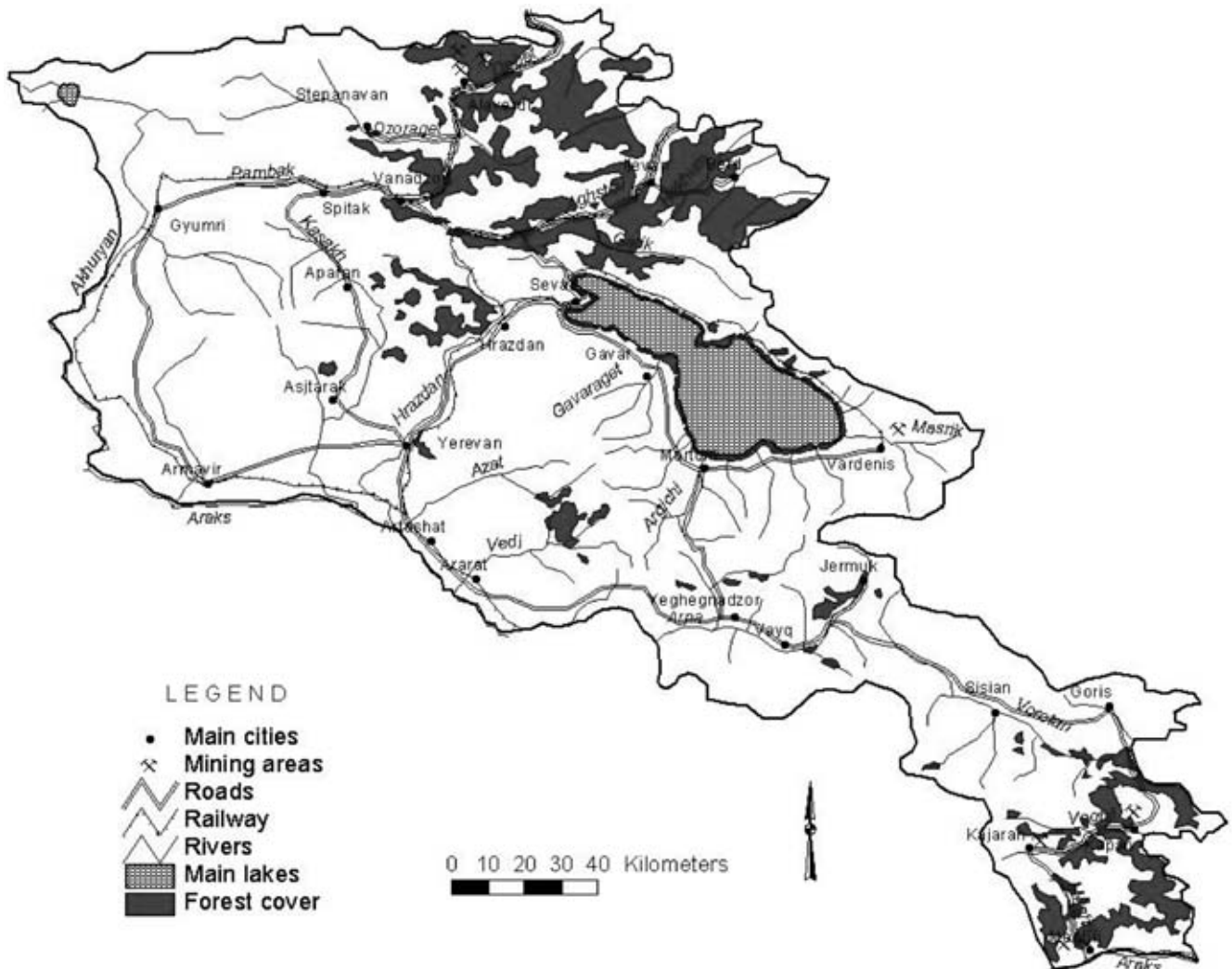
The decade of the 1990s was harsh and turbulent in Armenia. In 1991 Armenia got its independence from the former USSR. During the following year the country experienced political violence and several economic shocks. The separation from the USSR, compounded by a devastating earthquake in 1988, and the 1988-1994 war with the neighbouring Republic of Azerbaijan created a transportation, economic and energy blockade. This situation put a tremendous pressure on the forests as source of fuel wood. It is estimated that during the 1990s nearly 50% of the energy consumed in households near to forested areas came from fuelwood (Thuresson *et al.* 1999).

There has not been a forest inventory with national coverage since the declaration of independence in 1991. All the information regarding the current state of the Armenian forests is based on the last Soviet forest inventory in 1986-1989, and unfortunately many management decisions are still taken based on these data. In 1997-1999,

the Armenian forestry state agency 'Armforest' together with the Swedish National Board of Forestry (NBF) conducted a Forest Resources Assessment in Armenia that included only some parts of the country. According to this assessment the annual growth was provisionally estimated to be 2.86 m<sup>3</sup> per hectare per year, which is roughly twice as much as the previous official Soviet forest inventories Figures (1.4 m<sup>3</sup> per hectare per year) (Thuresson *et al.* 1999).

Authorized forest cuttings during the 1991-1996 period were close to 100 000 m<sup>3</sup> per year which satisfied 10-15% of the Armenian internal demand for timber products. It has been estimated that from 1997 to 2002 illegal forest cuts averaged at least 1 000 000 m<sup>3</sup> per year (Country Profile 2002). Results of the 1998 Armenian Forest Resources Assessment Project (Thuresson *et al.* 1999) show that both legal and illegal cuttings during the 1991-1996 period amount to 600 000 m<sup>3</sup> per year. There is not an accurate estimation of the current levels of cuts occurring in Armenia. In any case, these cutting levels are considerably higher than the most recent estimates of the mean annual growth of the Armenian forests which has been estimated to be 450 000 m<sup>3</sup> per year (Thuresson *et al.* 1999, Thuresson 2003). These numbers lead to the

FIGURE 7 Forest cover according to the 1986-1989 National Forest Inventory



conclusion that severe deforestation and/or degradation of the forests is occurring.

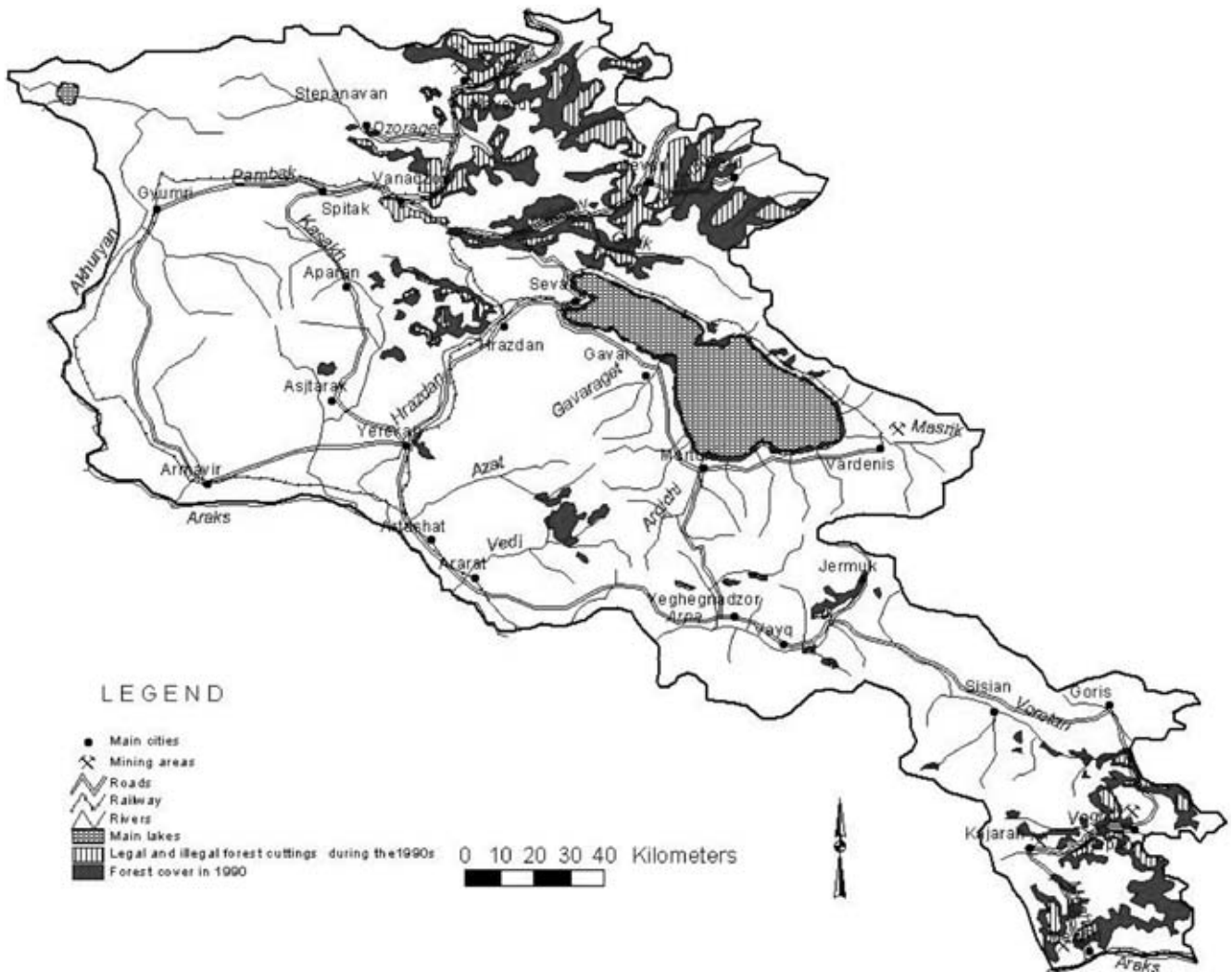
Examples of this deforestation and degradation process can be clearly seen in the basin of Lake Sevan where approximately a quarter of the forest plantations around the lake have been clear cut (Sayadyan 1997, Sayadyan 1999, Sayadyan and Nalbandyan 2002). Also, old high-quality mixed oak and beech forests are being replaced by young low-quality coppice hornbeam forests because of high-grade cuttings for illegal timber exports to Europe, Turkey and Iran (Thuresson 2003). In addition, important forest degradation processes are taking place due to the cutting of bushes in the very dry areas of southern and central Armenia, and to subsistence animal husbandry: The cuttings have accelerated erosion processes and have created conditions for mud flows during the short and intensive rains that occur in the summer in these regions (Sayadyan 1999). Many small owners became depend on sheep and cattle for their subsistence after the privatisation of the large collective farms. These animals usually forage in an unregulated manner in the meadows and grassland of state-owned forests.

**Estimation of the forest cover in the year 2000**

According to the most conservative estimates about 3 to 4% of the national forest cover has been destroyed since the 1986-1989 National Forest Inventory. This means that the forest cover has decreased from 11.2% of the national territory to 7-8% today (see Figure 8 and Table 3). In absolute values this is a decrease of 90 000 hectares or one fourth of the total forest cover that existed in 1988. The areas where legal and illegal forest cuttings are taking place are concentrated around large cities as well as small villages in the forested areas (see Figure 8) (American University of Armenia 1998, Country Profile 2002, Sayadyan and Nalbandyan 2002, Mitchell 2004, Sayadyan 2005).

During the late 1990s and early 2000s as the timber imports from Russia decreased to almost zero, the forest industry in Armenia depended on raw materials obtained mainly from illegal forest cuts. The extraction and consumption of fuelwood has decreased from the early 1990s levels due mostly to a regular supply of imported gas and electricity, however it is estimated that it is still

FIGURE 8 Estimated forest cover for the year 2000



high, particularly in towns and villages close to forested areas (Thuresson *et al.* 1999). People that got involved in the 1990s in the business of selling fuelwood cut illegally have evolved their activities to the production of materials for construction (e.g. doors, windows, and furniture), the production of high quality oak timber for brandy barrels, and more recently to the export of high quality oak, beech, and walnut timber to Europe, Turkey, and Iran. In this evolution, as their profits rose their operations have grown in size and sophistication.

Until a national forest inventory is carried out using the latest technologies and statistical methods, there is a high degree of uncertainty about the current extent and condition of the forest cover in Armenia. However, without a doubt, it can be stated that deforestation, high-grade cuttings, and degradation of the standing stock is occurring at an alarming rate. The estimated forest cover extent for the year 2000 shown in Figure 8 is based on the most recent and reliable reports by Thuresson *et al.* (1999), Country Profile (2002), Mitchell (2004), and Sayadyan (2005) as well as by extensive personal visits to the areas. The areas in Figure 8 where legal and illegal cuttings are occurring are subject to the highest rates of deforestation or degradation and hence are the most likely to rapidly deteriorate or disappear.

education of the international community and a new generation of Armenians. A picture (in our case a map) is worth a thousand words and this is especially true when trying to emphasise the urgent need to protect and regenerate Armenia's forests (compare Figures 4 and 8).

Although the economic conditions in the country have slowly improved in recent years, it is likely that the deforestation and degradation processes will take several years to slow down or reverse. Unless the Armenian people and the international community take drastic and effective action, the forests in the areas where unregulated forest cuts are taking place (see Figure 7) will likely disappear within the next few decades, leaving the country for all practical purposes devoid of forest cover.

The history of the Armenian people is closely related to its forests and it is not an exaggeration to assert that their future depends on them. The mitigation of some of the most critical environmental problems the country is facing today (erosion and water supplies depletion) is directly linked to the conservation and recuperation of the forest cover. With the historical and cartographical information presented here it is hoped that this paper has in a small way contributed to educating the international community and the Armenian scientists, managers, politicians and people about the history and current state of the forest cover in Armenia.

TABLE 3 *Armenian forests statistics*

Period	Forest cover (hectares)	% of total forest cover	Estimated timber volume (thousands m <sup>3</sup> )	Estimated volume per hectare (m <sup>3</sup> )
4000 to 1, B.C.	approx. 1 050 000 ha	35		
XVII and XVIII centuries	approx. 530 000 ha	18		
Maghakan 1941	284 379	9.6		
Abrahamyan 1960	241 753	8.1	24838.5	102.7
1966 National Forest Inventory	253 000	8.5	29700	117.4
Makhatadze 1977	273 000	9.2	27892	102.2
1978 National Forest Inventory	296 600	9.98	31140	105
1988 National Forest Inventory	334 100	11.2	41740	124.9
Estimation for 2000	approx. 245 000	8.2	35000	116.6

## DISCUSSION AND CONCLUSIONS

The results of this study allow us to present a consistent geographical representation of the evolution of the extent of the forest cover in Armenia. The most reliable direct and indirect sources of information were used to create conservative estimations of the forest cover during ancient times, the beginnings of the industrial era, and the beginning of 21<sup>st</sup> century. These estimations, although not perfect, give us an idea of the natural potential extent of the forests in Armenia, and the degree to which the Armenian forest resources have been destroyed. This information is valuable in at least two important ways. First, to assist in directing reforestation efforts by identifying areas that in the past have supported forest vegetation naturally, and second, in assisting in the

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