REPUBLIC OF AZERBAIJAN

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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

COMPARATIVE STUDY OF ECOLOGICAL FEATURES AND MANAGEMENT OF THE FAYA FORESTS OF THE REPUBLIC OF MALI AND AJINOHUR LOW MOUNTAINS ARID FORESTS OF AZERBAIJAN

Specialty: 2426.01 – Ecology

Field of Science: Biology

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Baku - 2024

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Dissertation Council FD 1.07 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Microbiology of ANAS

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INTRODUCTION

Actuality of research.

Despite the vital role of forests in sustaining life on Earth and ensuring human well-being, deforestation and forest degradation continue in many regions, often as a result of meeting the needs for timber, food, fuel and wood fiber. "*Many of the causes of deforestation go beyond the forestry sector and are rooted in broader socio-economic issues such as poverty reduction, urbanization and policies that favor land uses that generate greater and faster financial returns — for example, the development of agriculture, energy, mining and transport sectors"*[1].

The United Nations Strategic Plan for Forests 2017-2030 lays the groundwork for forestry-related contributions to the implementation of the 2030 Agenda for Sustainable Development, the Paris Agreement , the Convention on Biological Diversity, the United Nations Convention on combating desertification in those countries experiencing severe drought and desertification, especially in Africa, United Nations document on forests and other international forest-related instruments, processes, commitments and goals.

The overall vision of the United Nations is: to build a world in which all types of forests and tree plantations outside the forestlands are sustainably used, promote sustainable development and provide economic, social, environmental and cultural benefits to current and future generations.

From this point of view, it is clear that the research work devoted to the study of the protection and sustainable management of dry forests of the Republic of Mali in Africa and Azerbaijan, which are countries with few forests, is of great relevance.

Object and subject of research.

The object of research is the Ajinohur arid forests of Azerbaijan and the classified Faya forests of Mali. Ajinohur arid forests are located in the southern and southeastern parts of the low mountains of Ajinohur. The total area of the research object is 152544,53 ha. The Faya forest of Mali, the first forest classified by the authorities in

[1] La Charte Pastorale du Mali // LOI N°01-004 DU 27 FEV.2001. – Bamako-Mali : Parlement national, - 2001, - p.4

history, is the largest among many others, covering an area of nearly 80000 ha 40 km from the capital Bamako.

The subject of research is a comparative study of the ecological characteristics and management of the Faya forests of the Republic of Mali and the Ajinohur low-mountain arid forests of Azerbaijan.

Purpose and tasks of research.

The main purpose of this research is to study the ecological characteristics of two forest areas on different continents in order to compare them and develop a system for sustainable forest management in these areas.

To this end, the following tasks were defined:

- Study of ecological characteristics (relief, climate, hydrology, soil and vegetation cover, landscapes, fauna) of research objects;
- Identification of natural and anthropogenic factors affecting the degradation of Ajinohur and Faya forests;
- Carrying out monitoring of the state of forest resources in the study areas;
- Mapping of vegetation, landscapes in order to identify changes in the state of Ajinohur and Faya forests using GIS technologies;
- Comparison of the ecological state of the Faya forest, located in Mali, the country of the Sahel, and the arid forest of Ajinohur, located in the arid zone of the territory of the Republic of Azerbaijan.
- Development of a sustainable management system for the arid forests of Ajinohur and Faya.

Research methods.

During the dissertation work, environmental, botanical, mathematical-statistical, visual observations and laboratory research methods were used. Determination of coordinates in natural conditions was carried out using a GPS device. The maps presented in the dissertation were produced using ArcGIS 10.8 software.

Main provisions submitted for defense.

- The causes of degradation of dry forests, which have different natural, environmental and socio-economic conditions and

are located on different continents, are different, but also have similar aspects;

- Vegetation mapping using GIS technology plays an important role in forest monitoring;
- Based on the results of forest monitoring, it is possible to determine the level and direction of degradation processes occurring in them;
- The application of a sustainable forest management system is one of the main methods for protecting and restoring forests in countries with limited forest resources.

Scientific novelty of research.

For the first time, a comparative study of the natural and ecological state of the Azerbaijani forest with the African forest was carried out;

For the first time, studies were carried out to identify natural and anthropogenic factors of degradation of the arid forests of Ajinohur and Faya in a comparative context;

For the first time, monitoring of the state of the studied forests covering a 30-year period was carried out and maps were compiled using GIS technologies.

For the first time, systems for the sustainable management of Ajinohur and Faya dry forests have been developed.

Theoretical and practical significance of research.

The results of the research can be a decision-making tool for decision makers to plan and implement methods for managing and using arid forests to achieve specific environmental, economic, social and cultural goals, as well as to promote the protection, preservation and conservation of forests for sustainable development. Finally, it can be used as a guide for future researchers, also for the administrative, economic, legal, social, technical and scientific aspects of forest management.

Personal contribution of applicant. In carrying out all the experiments, PhD student played the main role.

Publication, aprobation and application of the dissertation. The research results are applied in the Biodiversity Conservation

Service at the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan.

The materials of the dissertation and the obtained scientific results were discussed at various scientific symposiums, sessions, scientific and practical conferences of the republican and international level: 2nd International Baku Scientific Researches Conference (Baku, 2021); 3rd International Ankara Multidisciplinary Studies Congress (Ankara, Turkey, 2021); 7th Middle East International Conference on Contemporary Science Studies (Lebanon, 2022); Green bridge through generations, (Almaty, Kazakhstan, 2022); Ecology and Soil Sciences in the XXI century (Baku, 2022); 11th International Conference Achievements and Challenges in Biology (Baku, 2022); "Ecology: problems of nature and society" Scientific conference (Baku, 2022); "Природно-ресурсный потенциал и экологическая реабилитация деградированных ландшафтов", Международная научно-практическая конференция (Россия, Грозный, 2023); VII International Scientific and Practical Conference "Scientific advances and innovative approaches" (Tokyo-Japan, 2023); VIII International scientific conference "The modern vector of the development of Science" (Philadelphia, USA, 2023).

17 papers (7 articles and 10 conference materials) have been published on the topic of the dissertation. Of these, 4 articles and 6 materials of the conference were published abroad.

Name of organization where dissertation work was carried out. The dissertation work was completed in the period from 2020 to 2023. The research was carried out at the Faculty of Ecology and Soil Science, at the Department of Bioecology of Baku State University; in natural conditions, on the territory of the Turyanchay Reserve of Azerbaijan and the Faya Forest in Mali.

The structure and volume of the dissertation. The dissertation consists of 216 pages, including an introduction, 5 chapters, conclusion and a reference of 157 titles and appendix. There are 13 maps, 45 tables and 32 figures.

In the research work: introduction is 7 pages, 10258 characters, chapter I –10 pages, 17883 characters, chapter II - 30 pages, 27200 characters, chapter III – 36 pages, 43713 characters, chapter IV - 54

pages, 66597 characters, chapter V – 58 pages, 80623 characters, conclusion – 2 pages, 2764 characters. The total volume of work (excluding figures, tables, graphs, appendix and references) is 123 pages with 213173 characters.

CHAPTER I
THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF FOREST MANAGEMENT

The section 1.1 highlight the theoretical and methodological foundations of forest management which accentuate the importance of global forest management and the potentiality of forest resources in Mali and Azerbaijan and their states.

The section 1.2 content the scientific and legal framework for forest management in the world in general and Mali and Azerbaijan specifically.

The section 1.3 shows the show the methodological approaches to resolve the issues raised. The general scheme of research on the classified forests of Mali and Ajinohur arid forests of Azerbaijan is based on methodological approaches proposed by scientists such as "*G.Sh. Mamedov, M.Yu. Khalilov"*[2], *"N.Tangara"*[3], *"I.Thomas and S. Samassekou"*[4], *"AGRECO"*[5], *"N'diaye"*[6] *and oth.*[7, 8, 9]. During the

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[2] Məmmədov, Q.Ş. Azərbaycanın meşələri / Q.Ş. Məmmədov, M.Y. Xəlilov. - Bakı: Elm, -2002. - 472 s.

[3] Tangara, N. Études de cas sur l'évaluation de la dégradation des forêts : extraites de l'inventaire forestier des forêts classées autour de Bamako / N. Tangara. - Bamako, -2009.- 28 p.

[4] Thomas, I. Rôle des forêts plantées et des arbres hors forêts dans la gestion durable des forêts : étude de cas de la république du Mali / I. Thomas, S. Samassekou. - Bamako : FAO Working Paper, -2003. - 73 p.

[5] AGRECO. Stratégie de communication dans le domaine du changement climatique et des forêts au Mali./AGRECO. -Bamako,- 2019.- 68 p.

[6] N'diaye, I. Elaboration du repertoire national des especes forestieres./ I. N'diaye.- Rapport d'activite,- Bamako- 2009.- 21 p.

[7] Флора Азербайджана [в 8 томах]. – Баку: АН Азерб. ССР, – 1950-1961.

[8] Pils, G. Flowers of Turkey (a photo guide) / G. Pils. – Austria: Friedrich VDV, – 2006. – 408 p.

[9] International Plant Names Index. URL: https://www.ipni.org/

dissertation work, "*environmental, botanical, mathematical-statistical*, *visual observations and laboratory research methods"* [10], [11], [12] were used.

The studies were conducted in 4 stages: desk-preparatory, field, laboratory and generalizing-final.

CHAPTER II
NATURAL-ECOLOGICAL CONDITION OF FAYA FORESTS

2.1 Analysis of the current state of the forest resources of the Republic of Mali.

Mali is a continental country in West Africa that is part of the area called the Sahel. Currently 90% of the population lives on 30% of the national territory, in the southern part of the country considered to be home to most of the forest formations. The flora of Mali presents varieties of species. There are 1739 spontaneous species distributed among 687 genera from 155 families. *"In Mali eight plant species are considered endemic: Maerua de-waillyi Aubrev. & Pellegr., Elatine fauquei Monod., Pteleopsis habeensis Aubrev, Hibiscus pseudohirtus Hochr., Acridocarpus monodii Arenes & P.Jaeger, Gilletiodendron glandulosum (Porteres) J.Leonard, Brachystelma medusanthemum J.-P.Leburn & Stork, Pandanus raynalii Huynh. Some species such as néré (Parkia biglobosa Jacq.), shea (Vitellaria paradoxa C. F. Gaertn.), balanzan (Acacia albida Delile), rônier (Borassus aethiopum Mart) have been preserved"*[13].

In 2020, the European Union in a report on the state of forests in Mali, estimated that 82% of forest areas have been destroyed since 1960 in Mali. "*In 2014, the country had only 788111 ha of forests compared to 4475000 ha in 1960"* [14].

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[10] Флора Азербайджана [в 8 томах]. – Баку: АН Азерб. ССР, – 1950-1961.

[11] Pils, G. Flowers of Turkey (a photo guide) / G. Pils. – Austria: Friedrich VDV, – 2006. – 408 p.

[12] International Plant Names Index. URL: https://www.ipni.org/

[13] PIRL. Programme d'inventaire des ressources ligneuses : Formations végétales / éd. DNEF- Bamako.-1990. -p.31

[14] MONGABAY. At least 500,000 ha of forest lost annually in Mali. URL:

2.2. The object of the research and its characteristics.

Located in an east-south-east direction from Bamako at 40 km, the Faya forest covering an area of 79947 ha. It is bounded by the parallels 12°30'N, 12°49'N and the meridians 7°40'W and 7°25'W.

The relief of the Faya is made up of slightly uneven plateaus. National road N°6 from Bamako to Ségou divides the Massif into two distinct zones;

• "*To the south, the landscape is marked by vast Bowe which connects with the colluvium or alluvium of the edges of rivers by fairly steep slopes (3 to 6^0 often more);*

• In the north, the topography softens to give a monotonous plain with a slope of around 1^0 "[15].

Geomorphology. It was pointed out in the geomorphological study that the classified forest was divided into two parts roughly separated by the Ségou road and with very different morphologies. The classified forest of Faya belongs to the Sotuba series, essentially made up of detrital rocks, made of feldspar and micas sandstone with siliceous and ferruginous cement.

Climate. Faya has a desert climate according to the Köppen-Geiger classification. Over the year, the average temperature in Faya is 28,7°C. The months of January and February are the driest months in terms of rainfall although it is the cold period in Mali overall. The heat wave of March and April causes the rain. It is in June that the rainy season begins in this area until October. In August, rainfall is the highest of the year with an average of 280 mm.

The hydrography of the classified forest of Faya is very rich. It is a tributary of the Niger river. It is made up of the Faya River and its tributaries. These rivers are temporary. In the watershed of the Faya River, there are 12 permanent water points at the level of the classified forest of Faya. The total area of the watershed in the classified forest of Faya is 75307 ha distributed among 17 sub-watersheds. The flood height in the Faya River often reaches 4 meters. The flood flow is estimated at 150m³ / second.

https://fr.mongabay.com/2021/07/au-moins-500-000-ha-de-foret-perdus-annuellement-au-mali/

[15] Sow, Y. The classified forest of Faya threatened with extinction // Inter de Bamako-Maliweb.net, - 2019, 6 May. – p.1.

Soil cover. The analyzes carried out show that 53,36% of the Faya forest area is covered by good soils (Tropical ferruginous soils and poorly developed soils) which are likely to support development work (regeneration assisted, pastoral enrichment, coppice treatments under forest). "*Lithosols (LITHIC LEPTOSOL) (on sandstone or ferruginous crusts associated with relict soils) occupy 29590,03 ha, (36,98%) and hydromorphic soils (EUTRIC GLEYSOL) occupy 7680.18 ha (9,60%)"* [16].

Landscape and vegetation. In the classified forest of Faya, there are essentially 6 types of plant formations:

Wooded savannah and Degraded galleries: these are strips of vegetation with more or less closed cover, located along certain watercourses and in depressions. They constitute an ecologically unstable and very fragile environment. These are the galleries which have undergone strong cutting pressure and whose regeneration has led to a savannah formation along the main watercourses. These are formations characterized by trees of very variable heights with a recovery rate of 40 to 60%. "*The species once composed of big feet of Isoberlinia doka Craib & Stapf, Paraniella oliveri Rolfe., Khaya senegalensis (Desr.) A. Juss which dominated the landscape of these galleries have almost given way to the releases of stumps of Terminalia sp, Combretum sp, Anogeisus leiocarpus DC (Guill), Pterocarpus erinaceus (Poir)., Isoberlinia doka Craib & Stapf, and Saba senegalensis (A.DC.) Pichon."* [17].

Wooded savannahs: continue to undergo various forms of anthropogenic degradation while the galleries, under strong pressure from operators, are dying. Production per hectare varies between 20 and 31$m^{3.}$ The average production observed is 24,43 m^3 /ha against 46,6 m^3 /ha in 1996. The characteristic species of wooded savannas are: *Guiera senegalensis* J.F.Gmel., *Detarium microcarpum* Guill. & Perr., *Ximenia Americana* L., *Bombax costatum* Pellegr. & Vuillet, *Cordyla pinnata* (A.Rich.) Milne-Redh., *Lannea acida* A.Rich.,

[16] Kaloga. B. Carte Pédologique des forêts classées de la Faya, de Tienfala et des Monts Mandingues // Pédologue ORSTOM. Institut national de la geographie.-1990. -p. 26-29

[17] PIRL. Programme d'inventaire des ressources ligneuses : Formations végétales / éd. DNEF- Bamako.-1990. -p.31

Pterocarpus erinaceus Poir. and *Sterculia setigera* Delile. Species like *Afrormosia laxiflora* Harms*, Isoberlinia doka* Craib & Stapf*; Khaya senegalensis* (Desr.) A.Juss., *Diospyros mespiliformis* Hochst. ex A.DC. are rare or even accidental.

***Degraded clear forests*:** these are arborescent vegetation colonizing fairly deep clayey silty soils. They occupy 15695 ha19,65% of the forest. These formations run along waterways and large alluvial depressions. They have an average production per hectare estimated at 19,75 m^3 against 25 to 40 m^3. The average coverage rate is 45%. The characteristic species, ie with a high frequency, are *Vitellaria paradoxa* C.F.Gaertn., *Terminalia macroptera* Guill. & Perr.*, Combretum glutinosum* Guill. & Perr.*, Anogeissus leiocarpa* Guill. & Perr., *Bombax costatum* Pellegr. & Vuillet, *Cordyla pinnata* (A.Rich.) Milne-Redh.*,* etc.

Shrub savannahs: These are formations generally resulting from the permanent and continuous degradation of vegetation under the common effect of human action and successive droughts. The recovery rate is 30%. They occupy a total area of 11350 ha, or 13,24% against an area of approximately 10274 and 10144 ha. The most common ligneous species are: *Vitellaria paradoxa* C.F.Gaertn.*, Combretum glutinosum* Guill. & Perr.*, Detarium microcarpum* Guill. & Perr., and *Sterculia setigera* Delile.

Shrub savannas and shrub savannas associated with bowe: they are characterized by an average cover varying between 15 and 25% with shrubs forming a rather discontinuous cover. Shrub savannahs are mainly located in the southern part of the massif, while shrub savannahs associated with bowe are located further north. They extend overall over a total area of approximately 37806 hectares 47% of the Faya classified forest. The average volumes per hectare are respectively 16,73 m^3 and 14,16 m^3. The main ligneous species most frequently encountered are: *Bombax costatum* Pellegr. & Vuillet, *Cordyla pinnata* (A.Rich.) Milne-Redh.*, Lannea acida* A.Rich., *Combretum micranthum* G.Don, *Sterculia setigera* Delile, *Combretum glutinosum* Guill. & Perr., *Pterocarpus erinaceus* Poir., *Lannea microcarpa* Engl. & K.Krause*,*. *Acacia ataxacantha* DC.

Plantations: the plantations were carried out between 1958 and 1989. They were carried out 4325,45 ha thanks to the work of the OAPF. Today these plantations have reached an area of 4531,08 ha. They are divided between 148 plots and 49 sub-plots. The plantations are mainly composed of exotic species: *Gmelina arborea* Roxb., *Tectona grandis* L., *Eucalyptus sp*, *Azadirachta indica* A.Juss. Alongside these plantations, there are reforestation trials carried out with the following species: *Anogeissus leiocarpa* Guill. & Perr. and *Khaya senegalensis* (Desr.) A. Juss*,* but without giving the expected results.

Fauna. A few years after the classification, the Faya still concealed an important and varied wildlife potential. There was the whole range of species of the savannah, both herbivorous and carnivorous. However, we note the presence of the following species: warthogs (*Phacochoerus aethipius*), patas (*Cercopithecus aethiops*), cynocephali (*Papio anubis*), and duikers (*Cephalophus grimmia*). The most common game birds are the common francolins (*Francolinus bicalcaratus*) and guinea fowl (*Numidiame leagrides*). As reptiles, "*the rivers of the Faya have always been home to crocodiles (Crocodilys niloticus), Seba Pytons (Sebea python), water and savannah monitors (Varanus nilotivus and Varanus exanthematics)"*[18].

CHAPTER III
NATURAL-ECOLOGICAL CONDITION OF THE AJINOHUR ARID FORESTS

3.1. Analysis of the current state of forest resources in the Republic of Azerbaijan.

The total area of the forest fund of Azerbaijan is 1213,7 thousand hectares and makes up 11,8% of the country's territory. The stock of root firewood is 148,8 million m^3, the forested area is 1021 thousand hectares, the forest area per capita is about 0,12 hectares. The Azerbaijan Republic's forests are unevenly distributed over its land. Thus, 48,7% of forests are found in the Greater Caucasus, 34,2% in

[18] Rapport national sur l'état de l'environnement :(rapport) / éd. MEADD – Bamako- Mali, - 2018. -147 p.

the Lesser Caucasus, 14,6% in the Lankaran-Talysh region, and 2,5% in the Kur-Araz plain and Nakhchivan MR.

3.2. The object of the research and its characteristics.

Ajinohur arid forests are located in the southern and southeastern parts of the low mountains of Ajinohur. Its territory starts from the eastern bank of the Alijanchay River and stretches in a narrow strip (5-6 km) to the east (45-50 km) to the eastern administrative borders of Goychay. The total area of the research object is 152544,53 ha. In the narrowest part of the area, its width is just over 2 km, in the widest part - almost 10 km.

Relief. The territory of the Ajinohur arid forests lies within the height range of 100-650 m above sea level. The relief of the region is characterized by the presence of relatively narrow anticlinal ridges and vast synclinal basins, stretching in the general Caucasian direction. "*The northern slopes are gentler and slightly dissected, while the southern slopes are steep, sharply dissected, steep, and strongly eroded"* [19].

Geomorphology. The territory is a relatively young geological formation and is composed of Tertiary and Quaternary continental deposits (alluvial-proluvial, deluvial, proluvial, deluvial-proluvial). In hilly-elevated and mountainous parts, soil-forming rocks are represented by deluvial-proluvial deposits, and in depressions and hollows, soil-forming rocks are mainly composed of weathering and denudation products brought from the area of hills and uplands.

Hydrography. Three large rivers flow on the territory of Ajinour arid forests: Alijanchay, Turianchay and Goychay, which originate from the high peaks of the Greater Caucasus. Crossing the foothills, they form gorges with steep and bare slopes, their height reaches 150-300 m, the width of the valleys along the bottom is more than 100 m. "*The density coefficient of the river network in the foothills is 0,30–0,50 km/km*^{2} "[20].

Climate. The climate of moderately warm semi-deserts and dry steppes with dry summers and winters and the climate is moderately

[19] Ширинов Н.Ш. Геологическое строение предгорий Южного склона Большого Кавказа / Н.Ш. Ширинов.- Баку: Азернешр, - 1962. - с.28

[20] Məmmədov, M. Azərbaycanın hidroqrafiyası / M. Məmmədov - Bakı: Nafta-Press, - 2002. - 266 s.

warm with dry winters prevail in the research area. The first type of climate is distributed up to an altitude of 400 m above sea level. It is distinguished by poor moisture (annual precipitation is 15-50% of the possible evaporation) and warm winters. The average annual rainfall is 300-400 mm. The second type is typical for the northern part of the territory within the heights of 400-650 m above sea level and is characterized by insignificant and moderate moisture (annual precipitation is 50-100% of possible evaporation), mild winters with little rain and moderately hot summers. The average annual rainfall is 400-500 mm.

Soil cover. Based on the generalization of the research "*of scientists"*[21],[22] in this area and our own research, the following types and subtypes of soils are common in the zone of Ajinour arid forests: mountain-forest brown soils (Eutric Cambisols); mountain forest brown steppe soils (Chromic Cambisols); mountain gray-brown soils (Yermic Cambisols); gray-brown soils (Cambisols); brown semi-desert soils (Gypsic Calsisols); alluvial-meadow-forest carbonate soils (Eutric Fluvisols). Based on a generalization of fund materials and own soil-field research, the dissertation provides a characteristic of soil fertility of the arid forest areas of Ajinohur.

Landscape and vegetation

On the territory of the Ajinohur arid forests, elements of several landscapes are combined, mainly forest, steppe, semi-steppe and semi-desert types of vegetation.

On the basis of "*Amanova's map "Natural landscapes of the Ajinohur foothills and adjacent territories""*[23], we created a Landscape map of the study area, the legend of which reflects the following types of landscapes are common in this area. Based on the

[21] Kərimova, L.R. Turyançay-Göyçay hövzə torpaqlarının ekoloji qiymətləndiirlməsi və monitorinqi: - /biologiya üzrə fəlsəfə doktoru dis. avtoreferatı./ - Bakı, 2009.- 19 s.

[22] Холина, Т.А. Экологическая оценка почв туранчайского государственного природного заповедника: /автореф. д-ра филос. по биол. наук, БГУ.- Баку, 2010.- 20 с.

[23] Amanova, Ş.S. Acinohur öndağliği və bitişik ərazilərin müasir landşaftlarinin transformasiyasinin ekocoğrafi xüsusiyyətləri. Coğrafiya üzrə fəlsəfə doktoru elmi dərəcəsi almaq üçün təqdim edilmiş dissertasiya, - 2017. -s.36-39

legend of the map, we calculated that in the foothills of Ajinohur the mountain-steppe landscape prevails (72,27%), the arid forests is in second place (10,3%), followed by mountain semi-desert landscape with 8,78% and lowland forests occupy 8,65% of the territory (Fig. 1).

Arid woodlands are a special type of xerophilous woody and shrubby vegetation. These relic rocks appeared, apparently, as early as the Tertiary period and were widespread in the foothills of the Greater and Lesser Caucasus at an altitude of 300–700 m above sea level . In the historical past, these forests covered a wider area, but improper exploitation, grazing and plowing of relatively sloping slopes have greatly reduced the area of these forests, and now arid forests make up only 3% of the forest fund of the republic.

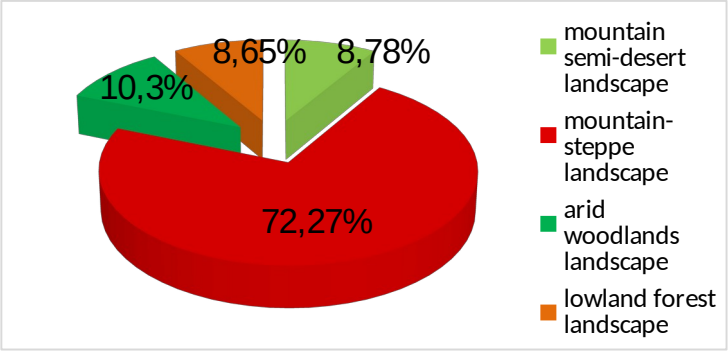

Fig. 1. Landscape structure of the Ajinohur foothills areas

The largest array of arid forests is protected on the territory of the Turianchay State Reserve. The main plants of arid forests are "*Juniperus excelsa subsp. polycarpos (K.Koch) Takht., Pistacia mutica Fisch. & C.A.Mey., Acer ibericum M.Bieb. Prunus amygdalus Batsch, Celtis australis subsp. caucasica (Willd.) C.C.Towns.*, *Pyrus salicifolia Balb.*" etc.[24]. Pistachio and juniper woodlands are spread on the Bozgir plateau at an absolute height of 500-650 m, between Turianchay and Goychay. Arid pistachio-juniper forests are found on the low slopes of the Turianchay valley against the background of a

[24] Məmmədov Q.Ş. Azərbaycanın meşələri / Q.Ş. Məmmədov, M.Y. Xəlilov.- Bakı: Elm, - 2002. - s. 293,328, 349, 363

wormwood semi-desert.

Fauna. Arid conditions, lack of water, incomplete vegetation cover, badland areas led to a decrease in the fauna in the study area. Wild boar, brown bear, badger, squirrel, fox, rabbit, jackal, lynx and other mammals and wild animals settled in the Ajinohur arid forests. Partridges, pigeons, griffon vulture, carrion eagles, black vulture, sparrows, blackbirds, warblers, autumn nightingales, mountain warblers, large and long-tailed honey birds and others live among local birds. In the reserve you can meet bears, falcons, golden eagles, steppe eagles, whose names are listed in the Red Book of Azerbaijan. For example, 12 species of mammals, 10 species of reptiles and 95 species of birds have been identified in the Turianchay Reserve.

CHAPTER IV
MONITORING OF THE STATE OF THE FAYA FORESTS OF MALI AND THE AJINOHUR ARID FORESTS OF AZERBAIJAN

4.1. Monitoring the state of the classified Faya forests of Mali

Here we were able to obtain maps based on the Landsat 5 instrument for 1990 (Figure 2) and Landsat8 for 2020 (Figure 3), which allowed us to monitor the state of forest formations and identify changes that have occurred over 30 years in the Faya forests.

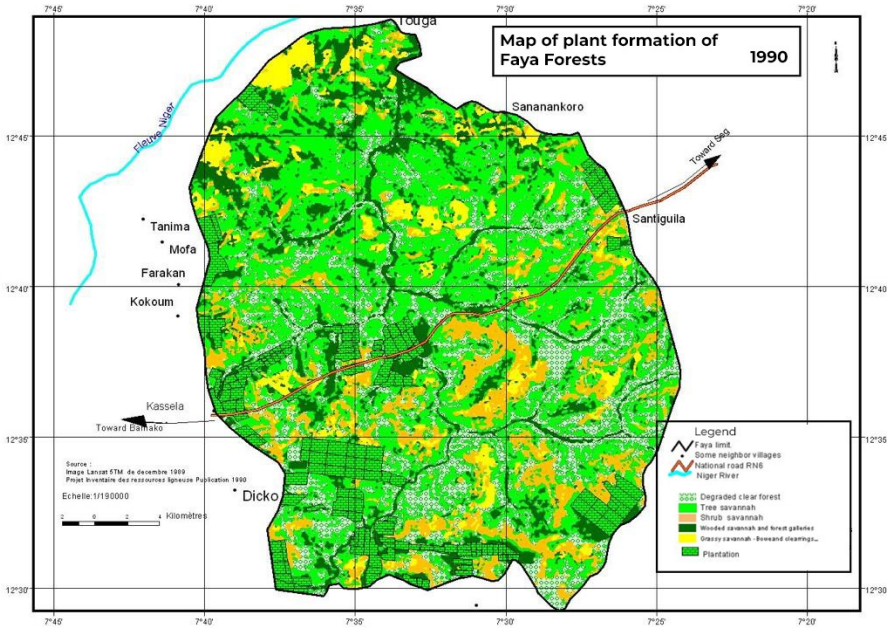

Figure 2. Map of plant formations of Faya forests in 1990

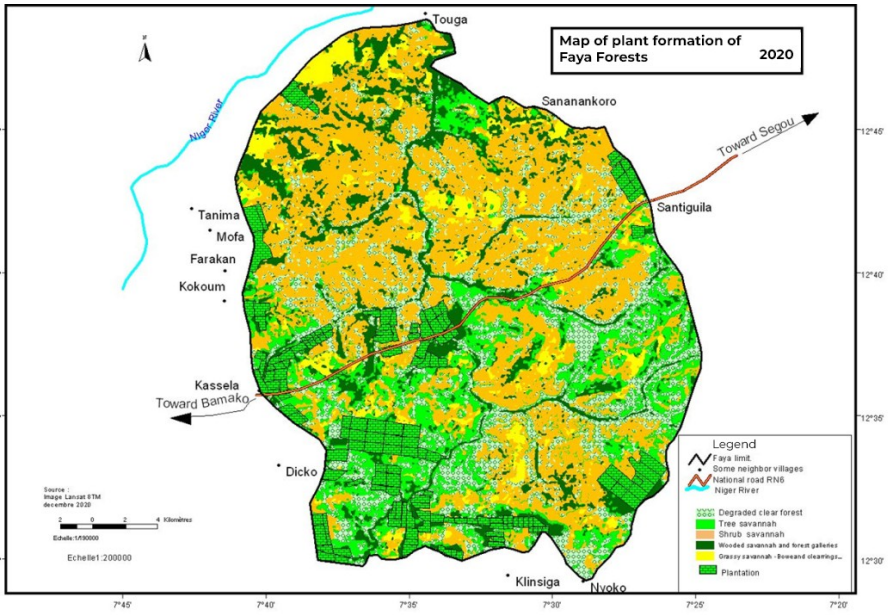

Figure 3. Map of plant formations of Faya forests in 2020

The tables below, taken from the information on the maps, will allow us to gain even greater accuracy regarding the surface covered by each of these formations.

Table 1.

Types of plant formations and its evolution of Faya forest area from 1990-2020

Types of plant formations	Area in 1990	Area in 2020	Evolution of forested areas from 1990 – 2020	
	Ha	Ha	ha	%
Wooded savannah and degraded galleries	12794	5250	-7544	-58.96
Degraded clear forests	10058	8195	-1863	-18,52
Tree Savannah	9954	6250	-3704	-37,21
Wooded Savannah	16220	9594	-6626	-40,85
Shrubby Savannah	21210	37374	+16164	+76,21
Grassy savannah - Bowé and clearing	5197	8770	+3573	+68,75

Plantations	4531,08	4531,08	-	-
Total	79964,08	79964,08	-	-

On analysis, it can be said that a large part of the area of this classified forest covered by the formations (wooded savannah, gallery forest, wooded savannah, tree savannah) has been transformed into shrubby savannah or grassy savannah, Bowé and clearing.

This tendency to degradation is also stronger in gallery forests. In 1990, it covered an area of 12794 ha or 16% of the total area of forest resources of Faya, in 2020, it covers an area of 5250 ha, or only 6,6%.

This can be explained by the effects of climate change which dry up the rivers that water these gallery forests or by anthropogenic pressures in the search for service timber which is abundant in this forest formation. In any case, the tendency to deterioration is very present.

The services that the Faya Forest offers yesterday and today are the same. These include: "*lumber, service wood, firewood, non-wood products, hunting, aerated fodder, etc*."[25]. Everything indicates that this forest is overexploited, hence the constant bitter reduction in the area of woody resources between 1990 and 2020 to 3832 ha.

The study revealed to us that there have been several programs for the preservation of this forest by different authorities but all of them turned out to be failures due to the bad design of the programs, the non-monitoring of the achievements, the bad interpretation of management and especially by many other anthropogenic factors including agricultural clearing, increased consumption of wood and charcoal, pastoralism, the removal of wood and service wood, sawn timber, pharmacopoeia, fishing, beekeeping, the needs socio-cultural, bush fires and harvesting for traditional medicine, etc.

4.2. Monitoring of the state of the Ajinohur arid forests of Azerbaijan

[25] Atteindre la neutralité en matière de dégradation des terres en république du Mali : : (Rapport national) / éd. MEADD - Bamako, - 2020. - p.23

We carried out environmental monitoring over a 30-year period to determine the level of anthropogenic changes in the arid woodlands of Ajinohur, which are the object of our research. For this, a remote method was used, based on Landsat maps (Landsat5 13.09.1990 and Landsat8 30.08.2020) (Figure 4, 5). These maps allowed us to know the change in the state of forest formations in Ajinohur over a period of 30 years and to establish the level of their state of degradation or improvement due to natural phenomena and anthropogenic pressures.

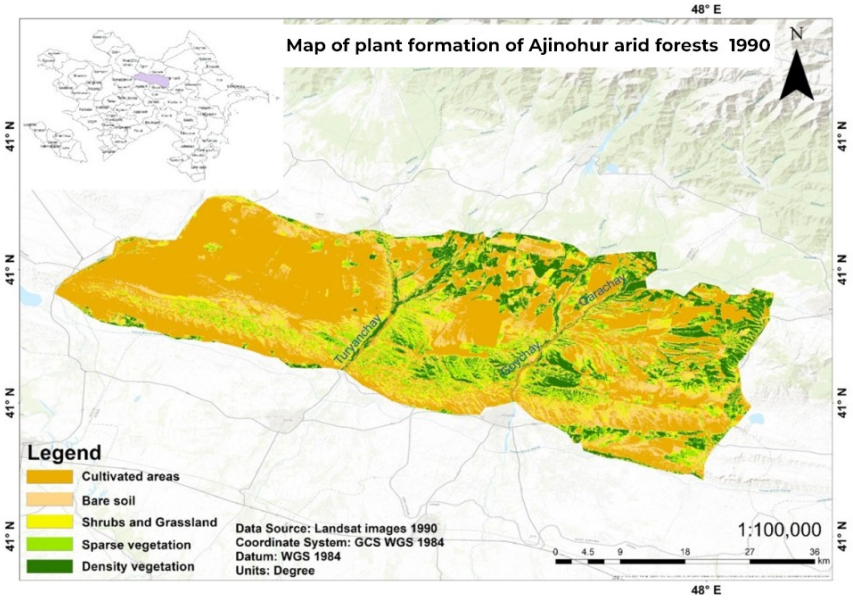

Figure 4. Map of plant formations of Ajinohur arid forest in 1990

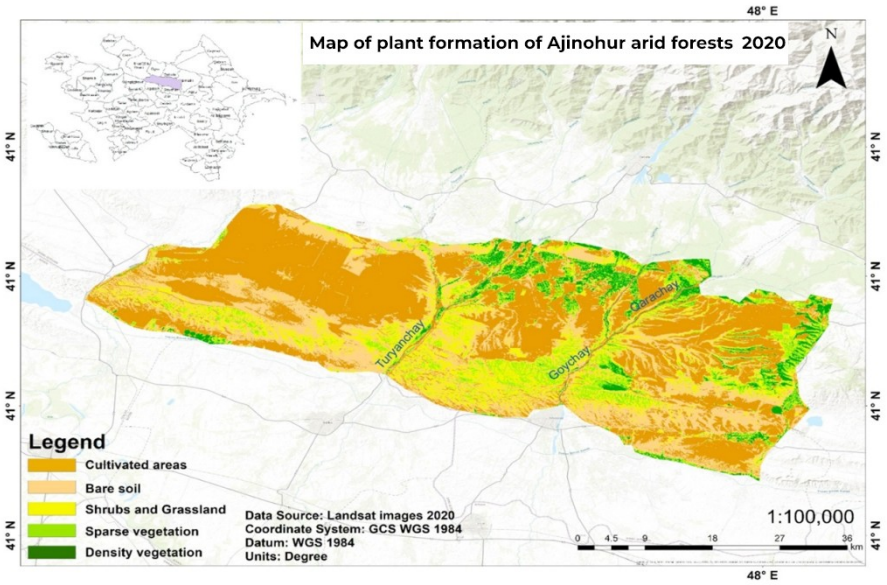

Figure 5. Map of plant formations of Ajinohur arid forest in 2020

The data given below in Table 2 are calculated on the basis of the information reflected on the maps.

Table 2.

Types of plant formations and its evolution of Ajinohur forest area from 1990-2020

Types of plant formations	Area in 1990	Area in 2020	Evolution of forested areas from 1990 – 2020	
	ha	ha	ha	%
Cultivated areas	70819,25	65145,1	-5674,15	-8,01
Bare soil	26823,61	35587,02	+8763,41	+32,67
Shrubs and Grassland	20529,27	32340,31	+11811,04	+57,53
Sparse vegetation	17513,79	11803,8	-5709,99	-32,60
Dense vegetation	16858,61	7668,3	-9190,31	-54,51
Total	152544,53	152544,53	-	-

According to the map showing the state of the Ajinohur dry woodlands for 2020, we see that the situation has worsened significantly. It can be seen that the area of cultivated land in agriculture decreased from 46% to 42%, while the area of pastures and shrubs increased from 13% to 21%. It can be seen that the area of dry woodlands and dense forests also decreased: the area of dry woodlands decreased from 17513,79 hectares to 11803,8 hectares, and the area of dense forests from 16858,61 hectares to 7668,3 hectares.

Thus, over 30 years, the area of cultivated land in the arid light forested zone has decreased by 8.01%. However, as a manifestation of the development of degradation processes, we also see that the area of rocky cliffs and barren soils has increased by +32,67%. The area of pastures and shrubs has also increased by almost half (+57,53%).

Due to anthropogenic pressure and ongoing degradation processes in the studied region, the area of arid woodlands decreased by 32,6%, and dense forests by almost 54,51%.

Anthropogenic impact on Ajinohur arid forests is observed in most cases with a negative result. These effects are manifested in animal husbandry, settlements, road building, and crop expansion.

The processing of slopes for agricultural crops, the intensive use of pastures and meadows, the destruction of forests, and the plowing of the soil create the basis for the intensification of the erosion process.

G.Sh.Mamedov and K.S.Asadov notes that the change of juniper and gums in dry woodlands and shrubs occurs as follows: Juniperus - Pistacia forest (cutting) → Juniperus-Pistacia woodlands, xerophilic shrubs (cutting) → xerophilic shibliak (grazing and erosion) → freegan sedge. The xerophyllic freegan is also transformed into sagebrush semi-deserts as a result of livestock grazing. Also characteristic is "*the formation of Pistacia forests as a result of cutting down Juniperus -Pistacia forests"*[26].

When analyzing the anthropogenic impact on the Ajinohur arid forests, the data created in the geographic database were analyzed.

[26] Məmmədov Q.Ş., Əsədov K.S. Meşə ekologiyası. Bakı, «Elm», 2010. s.369

Using the large-scale (1:100000) map "Anthropogenic transformation of the natural landscapes of the Ajinohur foothills and adjacent territories" compiled by *Amanova*[27], the map "Anthropogenic transformation of the Ajinohur arid forests" was prepared (Fig. 6.).

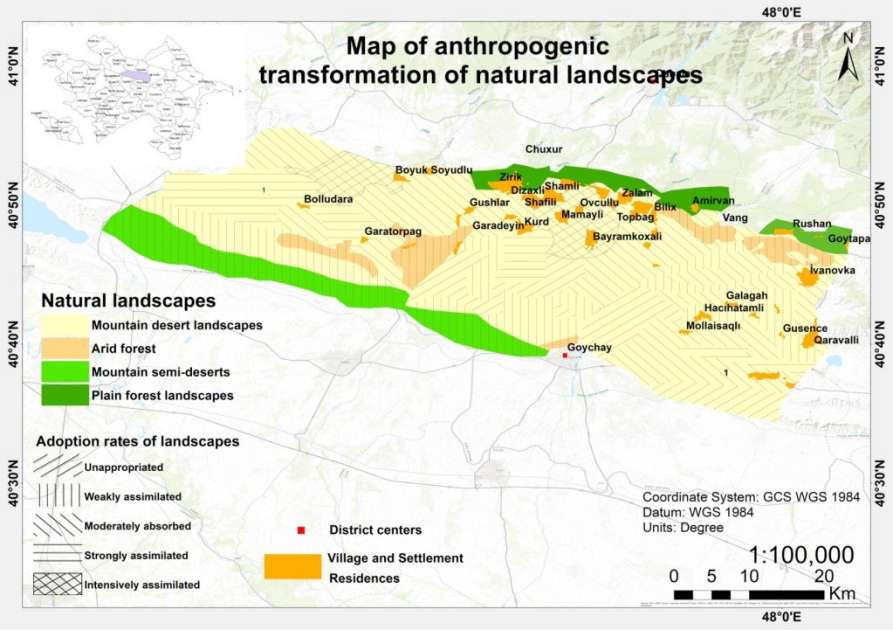

Figure 6. Map of anthropogenic transformation of arid forests of the Ajinohur foothills

When compiling this map, Amanova analyzed the statistical indicators of natural landscape types and, based on the results obtained, assessed the degree of landscape transformation. When assessing the degree of anthropogenic transformation of the Ajinohur foothills and adjacent territories, the author took into account such factors as the degree of land development, the degree of change in the amount of humus in the soil, plant productivity, NDVI index,

[27] Amanova, Ş.S. Acinohur öndağlığı və bitişik ərazilərin müasir landşaftlarinin transformasiyasinin ekocoğrafi xüsusiyyətləri. Coğrafiya üzrə fəlsəfə doktoru elmi dərəcəsi almaq üçün təqdim edilmiş dissertasiya, - 2017. -s.85

slope exposure, hypsometric conditions, slope steepness, the degree of horizontal and vertical fragmentation and their influence for landscape transformation.

We have determined the level of anthropogenic influence on the research area based on the "Map of anthropogenic transformation of arid forests of Ajinohur foothills" (Table 3).

Table 3.

Anthropogenic impact on the areas of the Ajinohur foothills

Change rate	Area	
	Ha	%
Unappropriated	17327,87	11,36
Weakly altered	50524,23	33,12
Strongly altered	24247,44	15,90
Moderately altered	50364,20	33,02
Intensively altered	10080,79	6,60
Total	152544,53	100

Relatively unchanged landscapes occupy 11,36% (17327.87 ha) of the study area. On 33,12% (50524.23 ha) of the study area, the degree of anthropogenic transformation is weak. 14% of these landscapes are covered with forests, and 25% belong to specially protected natural areas. The strongly altered landscapes are dominated by crop (54%) and pasture complexes (26%). Intensively altered landscapes are distributed by 6.6% (10080,79 ha), crops and settlements predominate. These landscapes almost completely cover the absolute heights of 100-680 m, with a slope of 0-20°.

It has been established that, 7,2% of arid sparse forest and shrub landscapes are relatively unchanged, 24,42% slightly modified, 36,52% moderately modified and 31,86% intensively modified anthropogenic landscapes. (Figure 7).

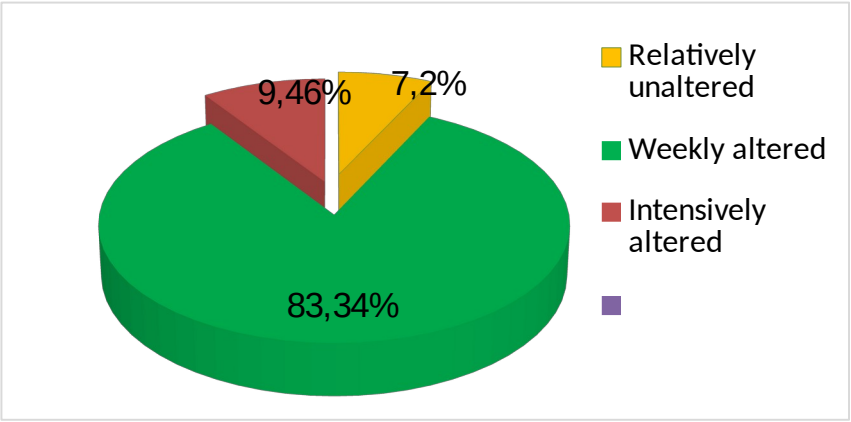

Figure 7. Anthropogenic transformation of the Ajinohur arid forests

CHAPTER V
THE MAIN DIRECTIONS OF IMPROVING THE MANAGEMENT EFFICIENCY OF THE FAYA FORESTS OF MALI AND THE AJINOHUR ARID FORESTS OF AZERBAIJAN

5.1. Optimization of forest management under conditions of limited resources.

Several optimal management of forest resources approaches grouped into three categories exist. These are the approaches: ecosystem, integrated and community. Optimal forest management also requires the implementation of the co-management system with all the stakeholders.

5.2. Comparative study of the state of the Faya forest of Mali and the Ajinohur arid forest of Azerbaijan.

A comparative description of the state of the Faya forest in Mali and the Ajinohur dry forest in Azerbaijan was carried out taking into account the following indicators of the compared territories: from a geographical point of view, from a hydrological point of view, from a climatic point of view, from the point of view of geological features and soil-forming rocks, from the point of view of soil cover,

from the point of view of landscape and vegetation, from the point of view of fauna, from the point of view of the influence of anthropogenic and natural factors and from the point of view of the management system.

5.3. Main directions of protection, restoration and reproduction of Ajinohur arid forest in Azerbaijan and Faya forest in Mali.

According to FAO, "*sustainable forest management is the process of planning and implementing practices for the stewardship and use of forests to meet specific environmental, economic, social and cultural objectives"*[28].

Based on the studies, we formulated the following main problems for the studied forests:

Social problems:

- Weak intersectoral cooperation (for example, forestry - energy);
- To stimulate sustainable forest management, it is necessary to strengthen control over forest owners (for Mali);
- Unauthorized collecting of firewood and non -timber forest products is illegal, but it is important for the well -being of local residents;
- To launch or complete the necessary reforms, there is often not enough political support (for Mali).

Ecological problems:

- Illegal cutting of trees;
- Uncontrolled grazing the livestock;
- Expansion of arable land;
- Soil degradation;
- Soil erosion;
- Soil salinization;
- Reducing biodiversity;
- Desertification and drying of rivers.

Economic problems:

- Weak continuous financing of measures related to SFM;

[28] Sustainable forest management. URL: https://www.fao.org/forestry/sfm/85084/en/, p.1

- Weak visibility of the forest sector in the economy as a whole;
- The non-timber forest products are most important for improving the well -being of local residents;
- There is no forest industry, the value of forest products is basically absent (for Mali);
- Insufficient use of ecosystem services;
- Ecotourism is not developed, but is considered as a potential source for income.

As a result of our scientific research, we have developed a system for sustainable management of the Faya forests in Mali and the Ajinohur dry forests in Azerbaijan, which includes 7 thematic elements, 8 criteria and 56 indicators (Table 4).

Table 4.

The structure of sustainable forest management for Ajinohur arid forest and classified Faya forests

No	Criteria	Indicators
1	Forest area	1.1. Forest area intended for production 1.2. The area of forests intended for protection. 1.3. The area and percentage of the total area of land covered with forest. 1.4. The area and share of forests to protect soil and water resources 1.5. Increase or decrease in forest area together with the cause 1.6. The area of restored forests 1.7. Pure annual forest growth in ha
2	Forest health	2.1. The area of damage is invasive and wood. 2.2. Damaged forests and other lands covered with forest, classified in accordance with the main factor in confirmation 2.3. The area and share of forests subject

		to the negative biotic process and factors (harmful insects, forest diseases, invasive species) that exceed natural indicators 2.4. Forest area damaged by drought. 2.5. The total area of burnt forests in percentage of the total area of forest lands. 2.6. Threats for forests caused directly by human activity.
3	Biodiversity	3.1. The area of protected forests in national parks, forestry and reserves. 3.2. A list of forest species (animals and plants) under the threat and entered in the Red Book 3.3. A number of species (wild relatives) representing a genetic fund
4	Protective functions	4.1. The area and share of forest lands, with significant degradation of the soil. 4.2. The share of forestry measures carried out in accordance with the highest achievements of forestry science and legislation. 4.3. The percentage of soil performance and water holding ability in forests. 4.4. The area and share of forests that are designed to protect soils or water resources 4.5. Budget funds
5	Production functions	5.1. Implementation of new technologies in production (forest recovery technologies, geoinformation technologies, etc.) 5.2. Production, consumption and export of non - timber forest products 5.3. Portion of consumers of non - timber forest products

		5.4. Forest inventory data, taxation for making economically significant decisions, implementation of the state economic strategy 5.5. Partnership to support SFM 5.6. The cost of services related to forests (beekeeping, collection of herbs, nuts and berries, hunting, grazing)
6	Socio-economic functions	6.1. Number of people employed in the forestry sector and labor costs, classified by sex, age, education and type of work performed 6.2. Number of new jobs created 6.3. Public participation in conflict resolution in decision-making 6.4. Education and retraining of specialists in the forest sector and other interested groups 6.5. Investment in the forestry sector (Total public and private investment in forestry) 6.6. Partnerships to support SFM 6.7. Annual investment in forest science and education 6.8. Number of implemented new technologies 6.9. Number of enterprises in percent 6.10. Consumer percentage 6.11. Food production, export of non-timber products 6.12. National and private investment in forestry 6.13. Sufficient budget for logistics 6.14. Prevalence and use of new technologies 6.15. Percentage of energy use from

		extractable forest resources compared to total energy consumption 6.16. Percentage of wood source energy supply 6.17. The number of increased mini-hydro, solar and wind stations
7	Place of work in the forestry sector.	7.1. Number of employees 7.2. Number of the village where the work was carried out 7.3. Sufficient staff to protect 7.4. Number of new jobs 7.5. Number of people employed in the forestry sector and labor costs classified by sex, age education and nature of work performed
8	People awareness	8.1. Number of visitors, pupils, students 8.2. Number of volunteers 8.3. Number of publications, TV and radio programs 8.4. Access to phone, TV, Internet and radio 8.5. Education, retraining of forest users 8.6. Number of trainings per year in schools, villages, etc. 8.7. Participation of people in information activities

RESULTS

1. Based on the conducted field and desk studies, the main natural and ecological features (relief, climate, hydrology, soil and vegetation cover, landscapes, wildlife) of the Ajinohur arid forests in Azerbaijan and the Faya forests in Mali were identified [8, 12].

2. Monitoring of the state of the Ajinohur and Faya forests covering 30 years (1990-2020) was carried out, on the basis of which the main natural and anthropogenic factors affecting the degradation of the Ajinohur and Faya forests were identified. It was found that in

the forests of Mali, over the course of 30 years, wooded savannah and gallery forests have lost 7544 hectares (58,96%), degraded clear forests lost 1863 ha (18,52%), but shrubby savannah increased by 76,21%. It has been established in Ajinohur that the state of dry woodlands for 2020 deteriorated significantly, the area of cultivated land in agriculture decreased from 46,43% to 42,70%, the area of Sparse vegetation decreased from 17513,79 hectares to 11803,8 hectares (-32,6%), and the area of dense forests - from 16858,61 hectares to 7668,3 ha (-54,51%), as a result of which the area of shrubs and grasslands increased from 20529,27 hectares to 32340,31 hectares (+57,53%) [10, 16,17].

3. Using GIS technologies, maps of the vegetation of the Ajinohur and Faya forests for 1990 and 2020 were compiled; as well as the map "Anthropogenic landscapes of the Ajinohur foothills", "Anthropogenic transformation of the Ajinohur arid forests", "Land use map of the Ajinohur arid forests" [10, 16,17].

4. On the basis of research, it was found that 7,2% of arid sparse forest and shrub landscapes of Ajinohur are relatively unchanged, 24,42% slightly modified, 36,52% moderately modified and 31,86% intensively modified anthropogenic landscapes, and 32,41% of the lowland forest landscape are slightly altered, 10,27% are moderately altered, 57,31% belong to intensively altered anthropogenic landscapes [14,17].

5. The main directions for the use of the forest resources of Ajinohur and the Malian forests of Faya have been identified (deforestation for agriculture, pastoralism, to meet the needs for wood, food, fuel and wood fiber, non-wood products, etc.) [3,4, 6,7,9].

6. A comparative description of the ecological state of the Faya forest, located in Mali, the country of the Sahel, and the Ajinohur forest, located in the arid zone of the Republic of Azerbaijan, is given. It has been established that despite the geographical remoteness of the two studied territories on two different continents, these forests have similar characteristics, given the aridity of their geographical areas, some elements of the climate, relief and anthropogenic pressure on forest resources; and differences in the

structure of vegetation and landscape, soil, climate, ways of managing forest resources, the level of anthropogenic pressure [13,15].

7. A system has been developed for the sustainable management of the Faya forests in Mali and the Ajinohur dry forests in Azerbaijan under resource limited conditions, which includes 7 thematic elements of sustainable forest management (forest resources and diversity, health and viability of the forest, productive and protective functions of forest resources, socio-economic functions, legal, political and institutional framework), 8 criteria and 56 indicators [1,5,11].

List of published scientific works on the subject of the dissertation

1. Togola, A. Issues and strategies forest management Malian: case of the classified forest of Faya // 2nd International Baku Scientific Researches Conference. Baku: 28-30 April, - 2021, - Vol 1, - p. 8-20.
2. Togola, A. Impacts of Climate Change on Agricultural Production in Mali: Risks, Vulnerable Sectors and Adaptation Measures // 3rd International Ankara Multidisciplinary Studies Congress. Ankara: 05-07 December, - 2021, - p. 61-72.
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4. Togola, A, Yusifova, M. Analysis of management strategies and prospects of the classified forest of Faya in Mali // Achievements and Challenges in Biology, XI International Scientific Conference devoted to 120th anniversary of professor Mirali Akhundov. Baku: 13-14 October, - 2022, - p. 333-334.
5. Yusifova, M, Togola, A. Preservation of woody forest resources through energy alternation in Mali: methods and advantages // Advances in Biology & Earth Sciences, - 2022, 7 (1), - p. 19-28.
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7. Yusifova, M, Togola, A. Issues and Challenges of forests protecting in Sahel countries // Вестник КазНУ. Серия экологическая, - 2022, 4(73), - p. 15-23.
8. Togola, A. Comparative study of the natural-ecological state of the Acinohur arid forests of Azerbaijan and the Faya forest of the Republic of Mali // Problems of nature and society dedicated to the 115 th anniversary of the birthday of Academician Hasan Aliyev. Baku: 19 December, - 2022, - p.228-229
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11. Togola, A. Analysis of management strategies and prospects of the classified forest of Faya in Mali // Azərbaycan Texnologiya

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12.Togola, A., Yusifova, M. Особенности ландшафтов Аджиноурского предгорья Азербайджана // Природно-ресурсный потенциал и экологическая реабилитация деградированных ландшафтов. Международная научно-практическая конференция. Грозный: 17-18 Марта, - 2023, - с. 379-382.
13.Togola, A., Yusifova, M. Energy Transition Policy and Biodiversity Protection in the Republic of Mali and Azerbaijan: Analysis of Potentialities and Assets for Sustainable Development // The Modern Vector of the Development of Science. VIII International Scientific and Practical Conference. USA-Philadelphia: 28-29 September, - 2023, - p. 9-16.
14.Togola, A., Yusifova, M. Application of GIS in the study of anthropogenic transformation of ecosystems in Ajinohur arid forests // VII International Scientific and Practical Conference "Scientific advances and innovative approaches". Tokyo. Japan: 02-03 November, -2023, - p. 24-28
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16.Togola, A. Cartographic analysis of anthropogenic impact on the Faya forest in Mali // "Gənc Tədqiqatçı", 2023, Vol IX, №3, - p.58-64
17.Togola, A. Anthropogenic impacts on Ajinohur arid forests of Azerbaijan / A. Togola, M.Yusifova, N. Sadigova [et al.] //Acta Biologica Sibirica, -2023, Volume 9, - p.1125-1140

The defense of dissertation will be held at "11⁰⁰" on June 05, 2024 at the meeting of the Dissertation council FD 1.07 operating at Institute of Microbiology of Ministry of Science and Education of the Republic of Azerbaijan

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The dissertation is available in the library of the Institute of Microbiology of MSE RA.

Electronic versions of the dissertation and abstract are posted on the official website of the Institute of Microbiology of MSE RA (https://www.azmbi.az/index.php/az/).

Abstract was sent to the required addresses on May 03, 2024.

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Signed for print: 01.05.2024
Paper format:60x84 $^{1}/_{16}$
Volume: 36228
Number of copies: 20