ISSN 1843-505X

FOREST AND SUSTAINABLE DEVELOPMENT

Proceedings of the Symposium
Brașov 2021

Universitatea Transilvania din Brașov
FACULTATEA DE SILVICULTURĂ ȘI EXPLOATĂRI FORESTIERE

Proceedings of the

9th International Symposium

FOREST AND SUSTAINABLE DEVELOPMENT

TRANSILVANIA **UNIVERSITY PRESS**
2021

Universitatea Transilvania din Brașov
FACULTATEA DE SILVICULTURĂ ȘI EXPLOATĂRI FORESTIERE

Proceedings of the

9^{th} International Symposium

FOREST AND SUSTAINABLE DEVELOPMENT

TRANSILVANIA UNIVERSITY PRESS
2021

Adress: 500091 Braşov
B-dul Iuliu Maniu 41A
Tel: +40 0268-476050
Fax: +40 0268 476051
E-mail: editura@unitbv.ro

Printed by:
Transilvania University Publishing House
B-dul Iuliu Maniu 41A
Tel: +40 0268 - 476050

The manuscripts were reviewed by members of the Scientific Committee and by 15 experts from universities and research organizations.

Universitatea
Transilvania
din Brașov
FACULTATEA DE SILVICULTURĂ
ȘI EXPLOATĂRI FORESTIERE

Proceedings of the

9th International Symposium

FOREST AND SUSTAINABLE DEVELOPMENT

Braşov, 16th of October 2020

TRANSILVANIA **UNIVERSITY PRESS**
2021

CONTENTS

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM "*FOREST AND SUSTAINABLE DEVELOPMENT*"
9TH EDITION, 16TH OF OCTOBER 2020, BRASOV, ROMANIA

FOREST ECOSYSTEM SERVICES FOR SUSTAINABLE DEVELOPMENT IN A PROTECTED AREA

Vasileios C. DROSOS[1*] Georgios TASIONAS[1]
Ioannis KOUKOULOS[1] Iordanis KASAPIDIS[1]
Vasileios STAVRIDIS[1] Ioannis SISMANIDIS[2]

Abstract: *In recent years there have been several attempts to record all the ecosystem services that can be provided by a forest. There are several classification schemes for ecosystem services with more representative ones MA (The Millennium Ecosystem Assessment), TEEB (The Economics of Ecosystems and Biodiversity) and CICES (The Common International Classification of Ecosystem Services). The concept of ecosystem services is linked with the contribution of the structures and functions of ecosystems to the maintenance and improvement of the quality of human life. Understanding this link is critical for a wide range of decision-making frameworks. National parks are protected areas by law and no intervention is allowed in their core. The Dadia - Lefkimi - Soufli National Forest Park is one of the most important protected areas at national, European, and international level. Opinions of mild interventions are expressed for the sustainable development of the wider area of the National Park, through systematic information, effective dialogue and promotion of strategic alliances between all political, productive and social actors that directly or indirectly influence the formation of spatial development options. Such views mean: ensuring equal living conditions and productive employment opportunities for citizens in this semi-mountainous region of the country, depending on their balanced structure of the population and demographic renewal, upgrading the quality of life of citizens and improving infrastructure, especially when there are problems of lagging development and environmental degradation, preservation, improvement, and promotion of residential and productive diversity, as well as natural diversity, with an emphasis on alternative crops, systematic protection, restoration, conservation and promotion of areas, settlements, landscapes, with natural elements, cultural and architectural heritage.*

Key words: *National Forest Park, MA, TEEB, CICES, cultural and architectural heritage.*

[1] Department of Forestry & Management of the Environment and Natural Resources, Democritus University of Thrace, Ath. Pantazidou 193 Str., Orestiada, GR 68200, Greece;
[2] Secondary Education,Directorate of Secondary Education, GR 66100 Drama, Greece;
Correspondence: Vasileios C. Drosos; email: vdrosos@fmenr.duth.gr.

1. Introduction

Ecosystems are stocks of natural capital that provide flows of tangible or intangible benefits for human welfare [5]. These benefits known as ES cover a wide range of products and services, as well as functions that sustain the ecosystems [8]; the body of knowledge on ecosystem services is very large but there is a general consent that important information on ecosystem services is still lacking. Parts of the environment in which the humans are developing their activity are characterized by various types of ecosystems. One way to account for landscape utilization, therefore, to manage the environment, which in turn may help in developing policies and strategies for a sustainable use, is that of using the concept of ecosystem services [6].

The Ecosystem Services (ES) concept has become increasingly popular in the last decades and it is usually employed to emphasize the contributions of ecosystems to human welfare. Although the recognition of the capacity of natural systems to provide benefits to society was already present, the concept of ES provides a framework where the contribution of ecosystems to societal wellbeing is highlighted.

Furthermore, this approach calls for a more fundamental multidisciplinary focus, promoting a dialogue between biology and economics [9] by considering both the ecological production and the economic value [2]. It allows to be distinguishing the contribution of benefits to society supplied by ecosystems from those provided by human capital or labour [1, 3], offering a framework to link changes in ecosystem processes and outputs to its effects on social welfare.

The most popular and widespread definition of ES is the one that is given by Burkhard and Maes [4] who stated that ES mean the contribution of the structures and functions of ecosystems in maintaining and improving the quality of human life.

According to several classification systems, ecosystem services belong to categories such as those encompassing provisioning, regulation, cultural and supporting services. Nevertheless, the provision of these services to a great extent depends on the existing biophysical conditions and the changes in space and time due to human-induced land cover change, land use and climatic changes, with rural people being the most vulnerable to such changes [10, 11].

The most common classification systems of ecosystem services are the: MEA (The Millennium Ecosystem Assessment), TEEB (The Economics of Ecosystems and Biodiversity), and CICES (The Common International Classification of Ecosystem Services).

According to MEA [10], ecosystem services are divided into four categories:

- Provisioning services are the products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources;
- Regulating services are the benefits people obtain from the regulation of ecosystem processes, such as air quality maintenance, erosion control or water purification;
- Cultural services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development,

recreation, and aesthetic experiences;
- Supporting services are those that are necessary to produce all other ecosystem services such as primary production, and soil formation.

TEEB is a global initiative focused on "making nature's values visible" [12]. According to TEEB [12], ecosystem services are divided into four categories, which are then divided into 22 subcategories [7]:
- Provisioning services;
- Cultural services and Amenity;
- Regulating services;
- Habitats services.

CICES provides a framework for classifying final ecosystem services that are dependent on living processes (biodiversity). CICES divides forest ecosystem services into [13]:
- Provisioning;
- Cultural;
- Regulation & Maintenance.

All the above systems recognize that forests, like other ecosystems, supply us with material goods that are difficult to find from other sources. These goods can be exchanged, traded, or consumed directly. These include wood, mushrooms, berries, aromatic and medicinal plants, prey, and biofuels.

Forests provide cultural services. They contribute to tourism and leisure. They increase the aesthetic value of an area and have a positive effect on the psychosynthesis of people who come even in visual contact with them. They are part of the folklore and traditions of every country.

Forests contribute to the regulation of the climate, temperature, water balance and wind speed. They protect against floods and erosion.

But the most important service offered by forests is related to the conservation of biodiversity. Biodiversity contributes to the stability of a system. The more components a system has, the less impact it receives by the alteration of one of them. In Greece, but also throughout Europe, the protection of biodiversity was favoured by the establishment of the European network of protected areas Natura 2000. Especially for the forests of Greece, a remarkable effort has been made to assess in economic terms the value of the services they offer.

Forest ecosystems are increasingly being influenced by human activity, including rapid expansion of urban land cover, which may alter forest processes, functions, and the ecosystem services that can be provided by a forest.

We still have relatively little understanding about the provision of forest ecosystem services notwithstanding the number of studies assessing the services provided by these ecosystems is constantly increasing.

The aim of this paper was to evaluate the forest ecosystem services of a protected area for a rational and sustainable development of it through mild intensity developmental measures.

2. Material and Methods

2.1. Research Area

The Dadia - Lefkimi - Soufli National Forest Park covers an area of 36,035.01 ha (Figure 1) and is lied between 40°58′00′′ to 41°15′00′′ N and 26°58′00′′ to 26°19′00′′ E (Table 1). The Dadia - Lefkimi - Soufli National Forest Park is broken down by land uses as shows in Table 2 (Figure 2).

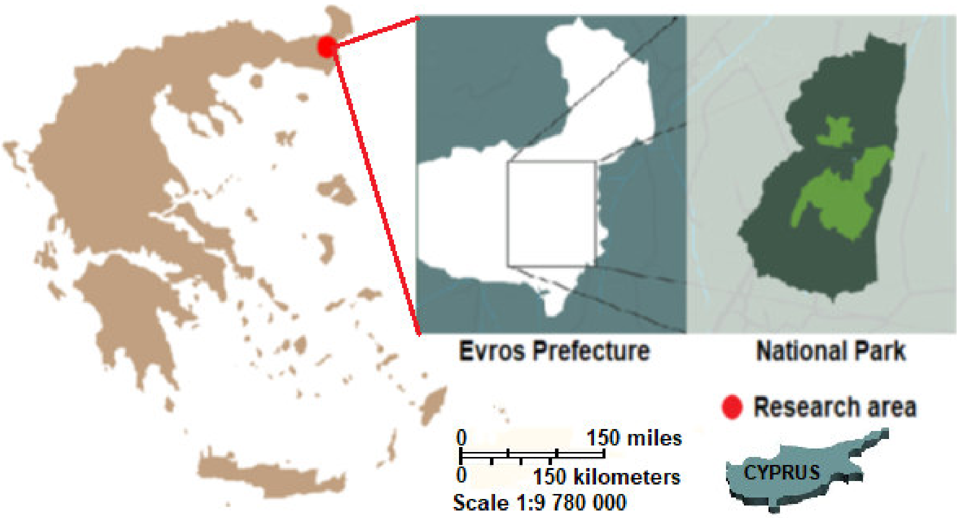


Fig. 1. *Research area*

Table 1

The boundaries of the Dadia – Lefkimi – Soufli National Forest Park

Bordered on	Bounded by
North	The borders of the former Communities Mandra, Protokklisiou, kiriaki and the boundaries of the forest Deriou – Aisymis
South	The borders of the former CommunitiesArdanio, Kavissou – Pilea
East	The National Road Alexandroupolis – Soufli – Orestiada
West	The administrative boundaries of the former Community Aisymis and the boundaries of the forest Deriou – Aisymis

Table 2

The Dadia – Lefkimi – Soufli National Forest Park's land uses

Serial Number	Land uses	Area [ha]	Percentage [%]
1	Forested areas	18,518.37	51.40
2	Partially forested areas	5,404.80	15.00
3	Evergreen and broadleaved	992.32	2.75
4	Agricultural lands	7,841.66	21.76
5	Barren lands, bare lands, firebreaks	2,965.70	8.23
6	Settlements	290.74	0.81
7	Dams and reservoirs	21.43	0.05
Total		36,035.01	100.00

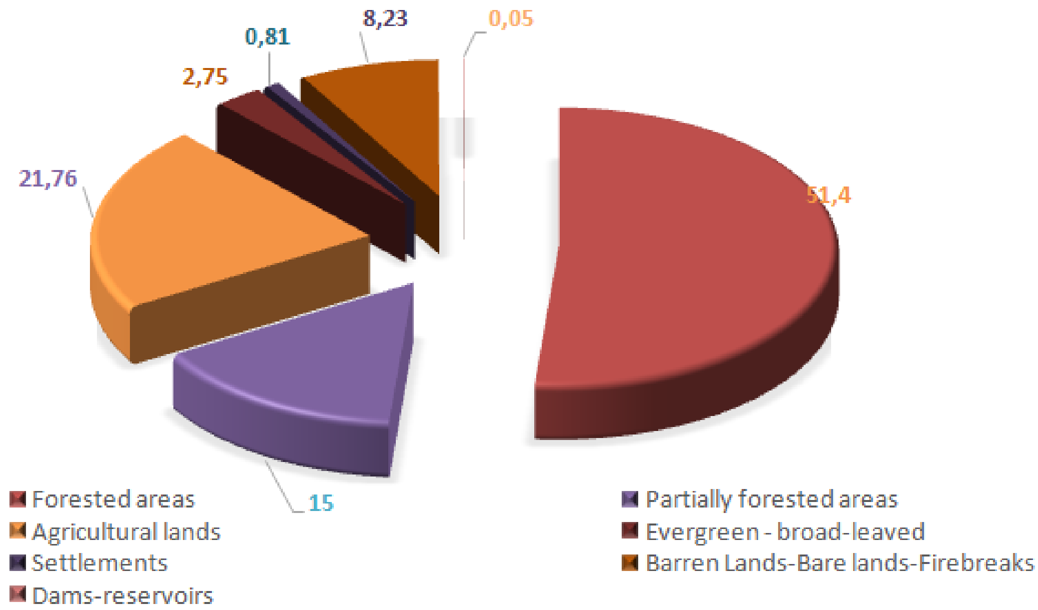


Fig. 2. *The Dadia - Lefkimi - Soufli National Forest Park'sland uses*

2.2. Description of the Ecosystem Services Derived from Natural or Ecological Environment

The landscape of Dadia - Lefkimi - Soufli National Forest Park is covered mostly by woodlands. The terrain is characterized by a turnover of small and large valleys, gentle and steep slopes, as well as a diverse hydrographic network with small and large streams. There are five major temporary torrential streams flows from W and NW and E and SE to the Evros River. During the summer, most of these streams retain pools of water supplying with clear water the entire region of the National Forest Park for humans, animals, and vegetation. The highest peak of the National Forest Park is Kapsalo at 620 m.

The climate of the region under study is Mediterranean (meso-Mediterranean), but its Mediterranean character is significantly modified by prevailing northern winds which gives a regionally harsh winter climate with continental affinities (Purification of air and water).

The area of the National Park presents a rich and diverse flora with species typically met in the Eu-Mediterranean and Para-Mediterranean vegetation zones. The composition of the forest, that covers the greatest part of the National Park, has been shaped in accordance to the climatic conditions in the area, geomorphology, soil and proximity to the Evros River (Regulation of water level – Protection of droughts and floods, Timber products – fuel wood and timber). Pine trees predominate in the area of the National Park, forming coniferous forests of Turkish pine (*Pinus brutia* Ten.), with black pine (*Pinus nigra* J.F. Arnold) found at the lowest altitudes of its known distribution, while forests of oak trees such as the Broadleaved oak (*Quercus frainetto* Ten.), the Turkey oak (*Quercus cerris* L.) and the Downy oak (*Quercus pubescens* Wild.) also occur over a large expanse together with maquis shrublands. Sclerophyllous shrubs, such as the Greek Strawberry tree (*Arbutus andrachne* L.), the Phillyrea (*Phillyrea latifolia* L.), the Treeheath (*Erica arborea* L.) and the Cretan rockrose (*Cistus creticus* L.) are mainly found in the south-western area along with 25 orchid species scattered throughout the National Park. At the south-western part of the National Park survives a small deciduous tree - the *Eriolobus trilobatus* (Poir.) C.K. Schneid (wild apple tree). This tree can be found only in Evros, having a low population of 150 trees. It is classified in the category of the rare and endangered species of the European flora. In what regards the riparian vegetation, the common Black alder (*Alnus glutinosa* (L.) Gaertn.) dominates most sites, while in others the Willow (*Salix spp.*), the Black poplar (*Populus nigra* L.) and the Athel tree (*Tamarix aphylla* (L.) Karst.) stand out (Non-timber products – medicine – roots – leaves, Biodiversity, Recreation and tourism – photography, Scientific field – for universities).

The rich combination of the landscapes creates an ideal biotope for the predator birds (Biodiversity). In the area are hosted 36 of the 38 European birds of prey, including rare species like the Eastern Imperial Eagle (*Aquila heliacal* Savigny) and the Lesser Spotted Eagle (*Aquila pomarina* Brehm). The Dadia - Lefkimi - Soufli National Forest Park is one of the unique areas in Europe where a high number rare species live together and also is the unique area where 3 of the 4 different species of vulture exist together: the Cinereous Vulture (*Aegypius monachus* Linnaeus), the Griffon Vulture (*Gyps fulvus* Hablizl) and the Egyptian Vulture (*Neophron percnopterus* Linnaeus) of Europe. The forest is the home for 20 couples of the Cinereous Vulture, and they are the only population in the entire south-eastern Europe. Also, it hosts approximately 60-65 mammal species (8 species are internationally recognized as endangered species) such as the wolves, bears, roe deer, otter, wildcat, wild boar (*Sus scrofa* Linnaeus), the stone marten (*Martes foina* Erxleben), the weasel (*Mustela nivalis* Linnaeus), the badger, squirrels, bats, and 41 reptile and amphibian species. Also, 17 different fish species have been recorded and 283 species of invertebrates were identified, 104 of which are butterflies.

2.3. Methodology

The methodology steps are the following:

1. Carrying out field investigation with data collection, based on sampling method and description of the stands. On the spot investigation of the existing conditions (Location and boundaries of the forest, forestry species composition, forest structure, management form, management classes, and access roads, facilities and settlements, etc.). For the field measurements were used GPS, compass, clinometer, and measuring tape;
2. Search and collection of the primary and secondary data from various stakeholders or from either public corporations or private organizations with the help of questionnaires and private interviews:
   - Data collection from municipalities (Socioeconomically-census data, grazing, hunting, tourism, protection etc.) with the help of questionnaires and private interviews;

- Data collection from Forest Service (meteorological data, ownership conditions, maps, data of prior management etc.) with private interviews;
- Cartographic and aerial material from the Military Geographical Service and the Ministry of Rural Development and Food (Topographic maps of various scales, recently taken aerial photos, orthophotomaps).

3. The methodology is that of the questionnaire, the results of which were stored in databases and in a geographic information system (ArcGIS); the data were processed (qualitatively and quantitatively), in order to propose possible and feasible solutions for the expected sustainable development of the area. The questionnaires were distributed to the residents in the area and were aimed to record both their professional and financial situation, as well as their views on the study issues. Taking into account the geographical location of Dadia - Lefkimi - Soufli National Forest Park, the terrain, the climate and the infrastructure that exist, it is possible for the geographic information systems to interconnect all levels of information (quantitative, qualitative, cartographic etc.). As a result, spatial maps can be created by combining the above depending on the case;
4. Drawing up conclusions and proposing policy measures to address conservation and the integrated sustainable development and management of the multifunctional GI protected areas in Greece.

3. Results and Discussion

3.1. Description of the Ecosystem Services Derived from Human Environment

The population of the three municipal departments of Dadia, Soufli, Likofi, Lagina, Lefkimi and Kornofolia amounts to 15,365 inhabitants. A series of local activities, endogenously driven and based upon local resources and practices still exist to give the area its present economic character. The main residents' occupations are agriculture, livestock farming, forestry (logging), viticulture, sericulture, beekeeping and lately, tourism (ecotourism).

Logging and forest management of the National Park have been interlinked with the residents' life for many years. Many residents cultivate the land, either as their main occupation, or in order to enhance their income. Viticulture along with sericulture have constituted the two main activities of the inhabitants of Soufli and of the wider region, bringing economic and demographic growth. Some silk craft industries and several commercial businesses operate in Soufli. Livestock farming activity is gradually dying out year after year nonetheless there are still animals freely grazing. Beekeeping holds a prominent position in the region, and it is dynamically growing in the wider area of the National Park. It is estimated that more than 100 tones of honey are produced per year (Food of vegetable origin, food of animal origin, timber products and non-timber products).

The outdoor recreation facilities are few, confined to the vulture feeding site and a couple of trekking paths and visitor services are rather poor. In "Katratzides", 9 km from Dadia, is a place for various sports and outdoor living facilities. Additionally, there are some ecotourism facilities (Recreation and tourism).

3.2. Description of the Ecosystem Services Derived from Cultural Environment

In the Dadia - Lefkimi - Soufli National Forest Park, which is under study in this paper, one can visit the information centre in order to have some information about the area and the diversity especially for the population of birds of prey and of course to see the observation post of them (birds of prey). The area's cultural history is manifested in e.g., a high number of sites of cultural and archaeological importance scattered over the area. The village of Dadia is a traditional settlement, featuring the monastery and old church of Prophet Elias. In the nearby Lefkimmi village, there is the 16th century church of Virgin Mary. Also, there are village ruins, stone-bridges, and various remains of ancient fortifications, mainly of Iron Age but also early Byzantine era, remnants of ancient settlements and many other historical sites. At the site of Anavra, three marble Roman sarcophagi have been discovered, as well as a carved rock, which according to tradition hosted a Byzantine church. In Lagyna, a stone-built tomb with semicircular arch, of Macedonian type has been discovered, dating back to the 4th century BC. On the top of AdaTepe the foundations of a stone-built fortress with five semicircular towers have been found. Someone can visit Soufli to admire the architecture of the town, the famous cocoon houses and Municipal Museum, Folklore Museum and Silk Art Museum of Soufli.

Special mention must be made of the very well-preserved parts of fossilized trees, which comprised part of a huge forest ecosystem c. 20–25 million years ago. It is considered to be the oldest petrified forest found on Greek territory. This important geological heritage extends today mainly over the low-lying, flat areas along the Evros River and only a small part reaches into the park. Knowledge of the ecological and cultural wealth of the area is a tool for conserving and respecting the area (Recreation and tourism, Scientific field and Ancestral practices and rituals).

In this research area, it is proposed to develop those forms of economic exploitation that are appropriate to its case, and the development intensity must be mild, in order not to have disturbances in the natural environment.

It would be good after considering all the ecosystem services derived from the natural or ecological environment, from cultural and human environment to pay attention to the following mild interventions in the research area:

- The definition of activities according to the management plan that concerns the wider region, to establish the non-management cores and peripheral zones accessible to the public;
- The construction and maintenance of the regional road network;
- Marking of mountain trails with an international trail and publication of special information maps for the information of the visitors;
- Upgrading the hotel infrastructure and services provided by all those involved in tourism professions (restaurants, cafes etc.);
- Establishing incentives for architectural urban planning upgrade;

- Connection of the whole developmental effort with the general one attempted in Greece;
- Promotion and protection of all monuments of the local architectural heritage (bridges, mansions, churches, chapels);
- Establishment of observatories for monitoring wildlife;
- Strengthening of the production of silk and the rearing of silkworms for this purpose and culture as an element of cultural heritage.

4. Conclusions

In summary the main benefits expected are:

- Ensuring a smooth and safe traffic of vehicles;
- Better monitoring, fire protection;
- Improving the competitiveness of forest products by reducing the large costs of handling and marketing;
- Increasing tourist traffic, and
- Strengthening the region's economy by increasing local employment; the stakeholders ought to take strategic decisions about the priorities for the region; these decisions should transfer the strategy into action and plans required for implementation.

The economic characteristics of the Dadia - Lefkimi - Soufli National Forest Park are shaped by many factors pertaining equally to the endogenous characteristics of the area's economy and to national economic importance of this border area. These two economic forces negotiate the development trajectories to be followed by the local economies and are often pulling in strongly diverging directions.

The geographical position gives it a special importance for national defense, but also puts it in the middle of a series of developments aimed at strengthening trade and energy links with neighboring countries. Investments to materialize these nation-wide development targets directly affect employment and economic activity, but also have an impact upon the overall character of the area, often jeopardizing the resources on which local economic activities depend. The establishment of renewable energy infrastructures in the area belongs in the same category of activities. On the other hand, a series of local activities, endogenously driven and based upon local resources and practices still exist to give to the area its present economic character. These activities include agriculture, stockbreeding, forestry and lately, tourism.

Each developmental project was designed to address the specific characteristics and needs (physiognomy) of each area with the least possible negative impacts. Particularly for vulnerable and sensitive semi mountainous areas, integrated development is not only necessary but also feasible.

References

1. Bateman I.J., Mace G.M., Fezzi C. et al., 2011. Economic analysis for ecosystem service assessments. In: Environmental and Resource Economics, vol. 48(2), pp. 177-218.
2. Bauer D.M., Johnston R. J., 2013. The economics of rural and agricultural ecosystem services: purism versus practicality. In: Agricultural and

Resource Economics Review, vol. 42(1), pp. III-XV.

3. Brown T.C., Bergstrom J.C., Loomis J.B., 2007. Defining, valuing and providing ecosystem good and services. In: Natural Resources Journal, vol. 47(2), pp. 329-376.
4. Burkhard B., Maes J. (Eds.), 2017. Mapping Ecosystem Services. Pensoft Publishers, Sofia, Bulgaria.
5. Calvet-Mir L., Gomez-Baggethum E., Reyes-Garcia V., 2012. Beyond food production: Ecosystem services provided by home gardens. A case study in VallFosca, Catalan Pyrenees, Northeastern Spain. In: Ecological Economics, vol. 74, pp. 153-160.
6. Castillo Vizuete D.D., Gavilanes Montoya A.V., Ricaurte Yepez C.B. et al., 2019. Perception and use of cultural ecosystem services among the Andean communities of Chimborazo reserve. In: Journal of Environment Engineering and Management, vol. 18(12), pp. 2705-2718.
7. de Groot R., Fisher B., Christie M. et al., 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In: The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations (ed. Kumar, P.). Earthscan, pp. 1-40.
8. Gavilanes Montoya A.V., Castillo Vizuete D.D., Morocho Toaza J.M. et al., 2019. Importance and use of Ecosystem Services provided by the Amazonian landscapes in Ecuador – Evaluation and spatial scaling of a representative area. In: Bulletin of the Transilvania University of Brasov, Series II: Forestry - Wood Industry – Agricultural Food Engineering, vol. 12(61), no. 2, pp. 1-26.
9. Lele S., Springate-Baginski O., Lakerveld R. et al., 2013. Ecosystem services: origins, contributions, pitfalls, and alternatives. In: Conservation and Society, vol. 11(4), pp. 343-358.
10. MEA, 2005. Millennium Ecosystem Assessment. Ecosystems and human well-being: wetlands and water. Online at: https://sci-hub.tw/10.1016/b978-0-12-409548-9.09206-x. Accessed on: 25 May, 2021.
11. Riitters K.H., Wickham J.D., Vogelmann J.E. et al., 2000. National Land-Cover Pattern Data. In: Ecology, vol. 81(2), p. 604.
12. TEEB, 2008. The Economics of Ecosystems and Biodiversity: An Interim report. Available online at: www.teebweb.org. Accessed on: 2 October, 2020.
13. Turkelboom F., Raquez P., Dufrêne M. et al., 2013. CICES going local: Ecosystem services classification adapted for a highly populated country. In book: Ecosystem Services: Global Issues, Local Practices (eds. Sander Jacobs, Nicolas Dendoncker, Hans Keune). Boston, pp. 223-247.

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM "*FOREST AND SUSTAINABLE DEVELOPMENT*"
9TH EDITION, 16TH OF OCTOBER 2020, BRASOV, ROMANIA

MULTICRITERIA DECISION MAKING TECHNIQUES FOR IMPROVED AND SUSTAINABLE FOREST ROAD ENGINEERING

Vasileios C. DROSOS[1] * **Georgios TASIONAS[1]**
Ioannis KOUKOULOS[1] **Iordanis KASAPIDIS[1]**
Vasileios STAVRIDIS[1] **Ioannis SISMANIDIS[2]**

Abstract: *Forest roads are widely recognized as the major source of disturbance in any forest development. Most of the forest roads in Greece are in the mountain region, characterized by steep terrain, with a dense river network, creeks, glens and springs. Thus, a large volume of works, consisting mainly in the construction of retaining walls, fords and culverts, is required for the protection and stabilization of roadbeds.*
Impact is defined as any change, positive or negative, caused by the characteristics of the environment, due to a project or activity. Impact assessment is the description and evaluation of potential significant effects on the various natural and socio-economic features of the environment.
The lack of specifications for an objective environmental impact assessment and then for the development of technical projects within the forest areas, with immediately measurable criteria, led us to assess the forest road with technical (quantitative) criteria, which are also qualitative indicators of impact on the environment. Multi-criteria evaluation (MCE) analysis (the implementation of decision-making rules to identify and enable the combination of many criteria, in the form of GIS layers, into a single map) and Geographic Information Systems (GIS) are two examples of tools that aid in the development of geographic data and maps for different purposes, such as conserving land for forestry uses and the quantitative and qualitative evaluation of the impact of the forest road on the environment.
The aim of this paper was to study the forest roads in terms of how it they are designed, constructed, and maintained, as well as whether they contribute to the sustainable development of the wider area.

Key words: *Road planning, Route selection, Road layout, Road construction and maintenance.*

[1] Forestry & Management of the Environment and Natural Resources, Democritus University of Thrace, Ath. Pantazidou 193 Str., Orestiada, GR 68200, Greece;
[2] Secondary Education, Directorate of Secondary Education, GR 66100 Drama, Greece;
Correspondence: Vasileios C. Drosos; email: vdrosos@fmenr.duth.gr.

1. Introduction

The first humans used forests as a source that gave them fuel, food, accommodation, water etc. As the years went the stone tools were replaced by metal ones and thus the industrial revolution begin and with it the construction of forest roads and forest works which had as a result the rise of productivity in both soil and material works. The potential that is given by the use of modern digging machines, apart from precious help, caused problems in the balance of the forest habitats [5].

The construction of a forest road must not be considered in advance from environmental point of view as negative because while being a true source of negative environmental impacts it also has many positive ones [2]. Opening assessment uses analytical and empirical methods. The analytical methods rely on theoretical models and consider quantitative opening criteria (expressed in monetary units) in relation to road density [1, 7]. Empirical methods apply knowledge of economic theory. Such methods are the dynamic methods. Among them, the method of cost-benefit analysis, takes into account only quantitative criteria and depends on road density, and the method of value - benefit analysis takes into account both quantitative and qualitative criteria (not expressed in monetary units). Both methods are applied in forest engineering [2].

For the first time, during 1977, an Environment Impact Assessment (E.I.A.) was undertaken in Greece, during the plan of dam construction in Aoos and Nestos rivers to produce electricity power. At the same year (1977), the E.I.A. was referred in the Law no. 743 [9] but without a practical use. In 1986, the E.I.A was referred in the Law no. 1650 [8] for the protection of Environment especially in articles 3-6, so that the Greek legislation can be adapted to EU directions.

In the forest road construction E.I.A. can be defined as the test if the road construction is compatible to the environment.

Forest roads are among the biggest investments that the Greek State will make in developing and managing its forests. The construction of forest roads also produces some of the biggest impacts on the forest and its associated values. These two considerations are reasons enough to explore the topic of forest roads with the specific aim of providing guidance on how to minimize both the impact and the cost of forest roads in order to ensure more sustainable forest ecology and more viable forest exploitation.

A forest is exploitable only through a good road network. Recently and following a worldwide lobbying on the degradation of the environment, countries were forced to impose laws for the protection of the environment. According to these laws, any construction work must be preceded by an environmental impact assessment to demonstrate impact during the construction as well as during the use of the work. The environmental effects to be examined are categorized as follows [3]:

- **Temporary or persisting**

Temporary effects appear during the construction, e.g. noise from the construction machinery, dust, while the persisting ones have continuous and stable influence, such as the change of the natural environment, noise, air pollution etc.

- **Accidental or anticipated**

The first ones include effects such as fire, environmental pollution due to accidents, while the second ones include the occupation of agricultural land leading to migration or shifting to other economic activities along with transfer of the population to urban centres.

- **Reversible or irreversible**

Reversible are the effects that can be eliminated through adequate measures or at least they can be maintained at very low levels. Irreversible are the ones that do not allow the environment to come back to its initial state. This second category may also be considered as persisting.

- **Fast developing or slowly developing**

The first ones occur during the construction or right after the completion of the work. The second ones may occur either during construction works or after their completion, but their effects appear much later e.g. effect on the flora and fauna.

The success of any activity and process depends fundamentally on the possibility of balancing (symmetry) needs and their satisfaction. That is, the ability to properly define a set of success indicators. The application of the developed new multi-criteria decision-making (MCDM) methods can be affected by decision-makers' subjectivity, which leads to consistency or symmetry in the weight values of the criteria. Many research papers from different countries explore aspects of multi-criteria modeling and optimization in crisp or uncertain environments. These papers propose new approaches and elaborate case studies in the following areas of applications: MCDM optimization in sustainable engineering, environmental sustainability in engineering processes, sustainable multi-criteria production and logistics processes planning, integrated approach for modeling processes in engineering, new trends in the multi-criteria evaluation of sustainable processes, multi-criteria decision-making in strategic management based on sustainable criteria [10].

Multi-criteria evaluation (MCE) analysis (the implementation of decision-making rules to identify and enable the combination of many criteria, in the form of GIS layers, into a single map) and Geographic Information Systems (GIS) are two examples of tools that aid in the development of geographic data and maps for different purposes, such as conserving land for forestry uses and the quantitative and qualitative evaluation of the impact of the forest road on the environment [4].

The aim of this paper was to study the forest roads in terms of how they are designed, constructed, and maintained, as well as whether they contribute to the sustainable development of wider areas. This is going to be achieved by the assessment of two alternatives of the same forest road by measurable criteria investigating the effect on the following environmental resources (components): the fauna, the flora, the water capacity (water resources, water saving), the soil, the disturbance of soil and rocky lands, the landscape-physiognomy and the acoustic environment.

2. Material and Methods
2.1. Research Area

The research area is the Public Forest of Vlastis – Emporiou in Kozani Prefecture in Greece.

Morphologically, the forest Vlastis - Emporiou has the characteristics of a mountain mass that is crossed by a large stream, Myricho. The transverse slopes range from the mildest and moderate, to strong and in some places steep, with moderate prevailing. It lies between 700 m (near the settlement of Emporio) to 1,700 m (1,703 anonymous peak of the Mouriki ridge). In general, the landscaping of the forest area is purely mountainous and as such must be treated from both an economic and a social point of view. The predominant aspects are north - northeast - east, but due to the intense relief, all the aspects are presented (Figures 1 and 2).

Fig. 1. *Research area in West Macedonia - Greece*

2.2. Methodology

The assessment method for the alternative routes are based on quantitative and qualitative criteria. Where possible, a form of benefit-value analysis [2] was used.

Stages of method application:

1. Two alternative routes were drawn (A and B). The A route has a total length of 4,600 m and the B route a total length of 3,700 m.

2. The criteria used to estimate the effects of each route were set out and the values (Z) for each criterion and alternative solution were calculated.

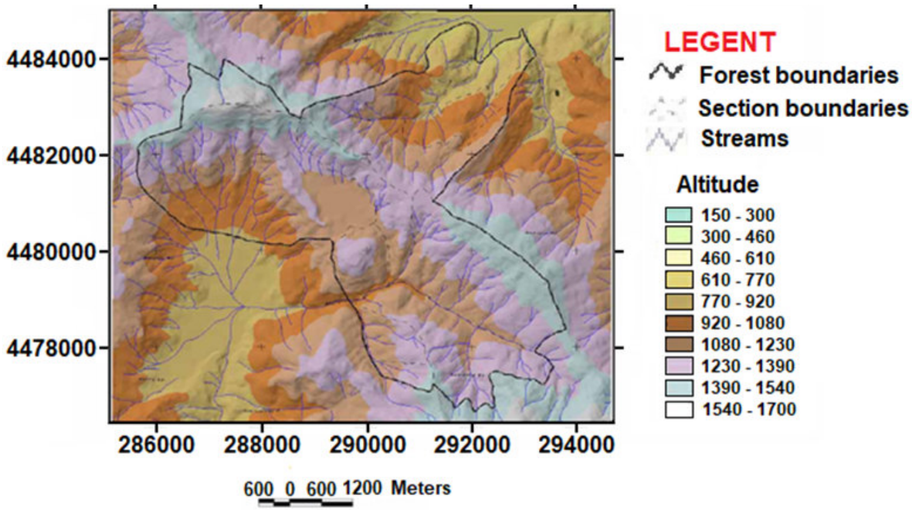


Fig. 2. *The digital terrain model of the research area*

Estimation criteria: Total costs of construction in €, the forest landscape in m^2/ha, the water saving in m^3/ha and the approximation of the area in running meters of forest road.

The forest landscape and the water saving (quality criteria) were estimated for the groups of environmental resources.

Prerequisites of grouping of environmental resources were: the ability to measure with one quantity (expression of quantity, Z), with an indicator (expression indicator) and with a unit, to be independent among each other but not to cover each other in respect to the estimation methodology.

The area's approximation criterion (quality criterion) was estimated based on the demand of the stakeholders for immediate access to the area in case of fire and was expressed with a length indicator of forest road and with units in running meters.

3. The importance of estimation criteria (weight, G) was calculated from a questionnaire sent to respondents.

4. The fulfillment degree or transformation coefficient (E) was calculated using the following formula (1):
- For a decreasing direction of estimation (when the quantity (Z) increases then the benefit is decreased) and
- For an increasing direction of estimation (when the quantity (Z) decreases then the benefit is increased):

$$Z = \frac{B}{Z} \qquad (1)$$

where:

Z is the expression of quantity (effect) of criterion;

B – the comparison size = average value of expression quantities of all criteria for each alternative solution;

E – a transformation coefficient.

Constraint:

$$E_{\min} \rangle 0 \quad \text{and} \quad E_{\max} \leq 3.2$$

When the quantity (Z) increases then the benefit is decreased in a decreasing direction of estimation.

When the quantity (Z) decreases then the benefit is increased in an increasing direction of estimation.

The quantities of criteria are expressed in different units. For the estimation and shaping into comparable numbers of benefit value to be possible, it is required to transform them into a non-dimensional scale. The transformed size is called fulfillment degree and is a non-dimensional number.

The partial values (G × E) were calculated for each criterion and alternative solution. The total has provided the total benefit value for each alternative solution. The alternative solution with the biggest benefit value is the most advantageous.

Materials: The data have resulted from a map with a scale 1:20,000, and field measurements such as the length of the forest roads, the average hill slope (45%), the occupation zone in m^2/ha, the amounts of earth fills in m^3/ha for a road 6 m wide, the construction cost and the questionnaire.

Afterwards, the absorptive capacity of the forest ecosystem of the effects from the forest road construction projects was studied. Specifically, the term absorption is defined by whether the impact effect will be absorbed from the forest ecosystem as time passes, as well as the number of impact receivers.

In order to determine the absorbency criteria and their weights the following steps were used:

i. The absorbency criteria were specified based on the related Greek and international literature [6];
ii. Their weights came from a questionnaire sent to scientists such as foresters of forest services and employees of the Private Forest Technical offices;
iii. The absorbency criteria were divided into 3 categories: 1st forestry criteria, 2nd topographic criteria and 3rd social criteria. The first two categories are related to the terrain conditions and for the third one with the distance.

The weights of the ***forestry criteria*** are three (3) and these are: the kind of coverage, the forestry species, the forest management form, age (forestry form), the height of the trees, the site quality and the productivity of the forest, and these are analyzed extensively below.

The weights of each of the ***topographic criteria,*** as was calculated from the questionnaire, are two (2) and these criteria are: the cross slope of the ground, the aspect and the relief. They are analyzed extensively below.

The weights of the ***social criteria*** are one (1) and this is the distance from: a tourist resort, from the national and country road network, from a railway, from an archaeological site, from an adjacent big city, from an adjacent village, from a European path and from a natural or artificial lake or river. All these are analyzed in detail below.

The grading of these criteria depends on the following principle:

We accepted a situation as ideal (=100%) for the forest protection by road construction. The percentage of deviation from this ideal situation will be subtracted from 100%. The result will be the grading of the criteria.

To grade the criteria, aerial photographs and digital orthophotos of the area were used as well as the management plan, the forest map of the complex and the geological map. For the onsite measurements modern surveying instruments were used.

In detail ***the forestry criteria*** are the following:

1. *The kind of coverage* – the percentage of the road that crosses: a forest is graded with excellent 100; a wooded area, depending on the density, with 25-50; and a bare land with 15;
2. *The forestry species* – the percentage of the road that crosses: a mixed forest is graded with excellent 100; a conifer forest with 70; and a broadleaf forest with 50-80 depending on the season when measurements are carried out, that is if trees have leaves or not;
3. *The forest management form* – the percentage of the road that crosses: a seedling (high) forest is graded with excellent 100; a coppice forest is graded with 50 and a composited or middle form forest is graded with 75 to 100 depending on the seedling-coppice forest rate;
4. *Age (forestry form)* – the percentage of the road that crosses: a group-selective forest is graded with excellent 100, a selection forest with 75 and an even-aged forest with 50.
5. *The height of the trees – the* percentage of the road that passes among large trees >20m is graded with excellent 100; medium size trees 10-20m with 75 and small trees <10m with 25 to 50 depending on their height.
6. *The site quality* – good (first and second site quality), medium (third and fourth site quality) and poor (fifth and sixth site quality). The percentage of the road that crosses good site quality is graded with excellent 100, medium with 50 and poor with 25.
7. *The productivity of the forest:*
   - Category I: over $3m^3$/year/ha;
   - Category II: 1-$3m^3$/year/ha;
   - Category III: less than $1m^3$/year/ha.

The percentage of the road that crosses through forest of category I productivity is graded with excellent 100, forest of category II productivity with 50 and forest of category III productivity with 25.

In detail ***the topographic criteria*** are the following:

1. *The cross (transverse) slope of the ground* – the percentage of the road that crosses from gentle slopes <8% is graded with excellent 100, from moderate slopes 8%-20% with 50 and strong (intense) slopes >20% with 25 to 5, depending on the slope;
2. *The aspect* – the percentage of the road that crosses from an altitude less than 1000m with northerly aspect is graded with excellent 100, southerly with 50 and easterly aspect - westerly aspect with 75; the percentage of the road that crosses from an altitude over 1000m, with easterly or westerly aspect is graded with excellent 100, and northerly or southerly aspect with 70;

3. *The relief* – the percentage of the road that crosses through a mild relief is graded with excellent 100, a multifarious relief is a rich relief with continuous mountain ranges and deep ravines.

Social criteria depend on the number of people affected by the road. Distance plays a major role in impact, via:

1. *Distance from a tourist resort* – since tourism is seasonal and is very intense during the peak season, each kilometer of the distance from the resort increases grading e.g. distance 0-1 km is graded with 0, 1-2 km with 10, 2-3 km with 30 etc.;
2. *Distance from the national and provincial road network* (the same as with the resort);
3. *Distance from a railway line* - it has no direct impact but if one sees the road from the train, he/she might want to visit the forest soon by car. However, it has impact due to noise;
4. *Distance from an archaeological site* – the same grading as with the resort;
5. *Distance from an adjacent big city* – the same grading as with the resort;
6. *Distance from an adjacent village* – the same grading as with the resort;
7. *Distance from a European path every time the road crosses the path, its grading is reduced* – e.g. if it crosses the path once it is graded with 80, if twice with 60, 3 times with 40 etc.;
8. *Distance from a natural or artificial lake or river* - the same grading as with the resort).

The forestry and topographic criteria can be estimated digitally; while criteria 3, 4, 5, 6 and 7 from the forestry ones can be estimated from the management plan or by the terrestrial measurements. The social criteria are assessed with special software, displaying on the P/C screen what is observed from a different DTM point.

First, in order to calculate the mean absorbency value (C_A), we multiply the grading of each criterion (A) with its weight (W_A) and in the end we divide the sum of the products with the total sum of weights. This value is the mean absorbency value on a scale of 100 (%).

$$C_A = \frac{\sum (A \cdot W_A)}{\sum W_A} \qquad (1)$$

where:

C_A is the mean absorbency value, for matrix as size %.

A – the grading of each criterion, for matrix as size [%];

W_A – the respective weight coefficient, absolute number;

$\sum (A \cdot W_A)$ – the sum of the estimate absorbency multiplied with the respective weight coefficient, for matrix as size [%];

$\sum W_A$ – the sum of the weight coefficient values, absolute number.

3. Results and Discussion

From the assessment of the two alternatives of the same forest road by setting up measurable criteria the effect on the following environmental resources (components) were investigated: the fauna, the flora, the water capacity (water resources, water saving), the soil, the disturbance of soil and rocky lands, the landscape-physiognomy and the acoustic environment.

Fauna: Local temporary disturbances are expected during the construction phase while during the working operation phase; no impacts on the forest's roads are expected. Expression indicator is the occupation zone of forest roads in m^2/ha.

Flora: A permanent impact on the flora is expected during the construction phase due to loss of vegetation. The impact is expected to reduce over time due to the natural or artificial regeneration of the slopes on the forest roads, but a small degree of vegetation loss is expected during the phase of the working operation of forest roads. Expression indicator is the occupation zone of forest roads in m^2/ha.

Water capacity (water resource): The construction of forest roads is not expected to have large effects on the aquatic environment. Expression indicator is the volume of earth fills in m^3/ha.

Soil: A permanent loss of the soil layer is expected. The impact is expected to decrease over time, and it will be of limited extent during the operation phase as long as the appropriate measures are taken. Expression indicator is the occupation zone of forest road in m^2/ha.

Balance of soil and rocky lands: It is expected that, during the construction phase, rocks may become temporarily unstable in the earth fill; the slopes will be of limited importance during this phase. Expression indicator is the volume of earth fills in m^3/ha in combination with the height and the gradient of slopes.

Acoustic environment: Noise from the explosions and from machinery will temporarily affect the local fauna during construction. Expression indicator is the volume of rocky masses and the type and number of machines used for the implementation of the works.

Landscape-physiognomy: The physiognomy and the harmony of the micro-landscape will be adversely affected during construction due to the removal of vegetation which will take place during the phase of construction of the forest road and the surface layout. The impact is expected to continue beyond the phase of construction into the operational phase of the forest road but is expected to be limited. Expression indicator is the occupation zone in m^3/ha in combination with the created earth fills.

Table 1

Estimation and hierarchy of alternative solutions

Estimation Criteria	Z		Expression		Weight	E = B / Z		G × E	
	A	B	Indicator	Unit	(G)	A	B	A	B
Costs of construction	160	113	Cost	€	30	3	3.2	90	96
Forest landscape	140	104	Occupation zone	m^2/ha	20	2	2.5	40	50
Water Saving	35	28	Volume of earth fills	m^3/ha	15	2.1	3	31.5	45
Approximation	4600	3700	Length	m	35	0.2408	0.3610	8.43	12.6
Total Benefit Value								169.9	203.6
Hierarchy								2	1

Table 2

Absorbency criteria of the forest roads A and B in the forest area

	Absorbency Criteria	Weights	A [%]		B [%]	
			Grade	Sum	Grade	Sum
1	2	3	4	5 = 3 × 4	6	7 = 3 × 6
Terrain conditions						
	Forestry criteria					
1.	Kind of coverage	3	100	300	80	240
2.	Forestry species	3	100	300	100	300
3.	Forest management form	3	100	300	100	300
4.	Forestry form (age)	3	80	240	70	210
5.	Tree height	3	40	120	75	225
6.	Site quality	3	50	150	50	150
7.	Forest productivity (harvesting)	3	50	150	50	150
	Topographic criteria					
8.	Slope of ground	2	20	40	60	120
9.	Aspect	2	70	140	70	140
10.	Relief	2	100	200	80	160
Social criteria						
	Distance from					
11.	Tourist recreation area	1	90	90	90	90
12.	National or provincial road network	1	100	100	90	90
13.	Railway	1	100	100	100	100
14.	Archaeological site	1	100	100	100	100
15.	Adjacent big city	1	100	100	100	100
16.	Adjacent village	1	50	50	70	70
17.	European path	1	100	100	100	100
18.	Natural or artificial lake or river	1	40	40	100	100
Total		35		2620.00		2745.00
Absorption coefficient value: $C_A = \frac{\sum(A \cdot W_A)}{\sum W_A}$				74.86%		78.43%

Based on the expression indicators, the environmental resources were classified in two groups; those that are expressed by the occupation zone and with the criterion of the forest landscape, and those with the volumes of earth fills and with the criterion of water saving.

The following Tables 1 and 2 presents the estimation and hierarchy of alternative solutions and the absorbency criteria for the roads in the research area.

Table 1 shows the results of estimation and hierarchy of the alternative solutions (A and B). Solution (B) has the biggest benefit value (203.6) and is considered more advantageous than (A) with total benefit value (169.9). The selection of (B) is mainly due to its degree of fulfillment (transformation coefficient) (0.3610) which is bigger than (A).

Table 2 shows the estimated environmental impact of the two routes. The absorption coefficient (78.43%) of the solution (B) is bigger than (A) 3.5 unit about. This difference is due to kind of coverage, tree height, slope and adjacent village. So, because these differences and with regard to the differences in benefit-value analysis shown in Table 2 we consider solution (B) more advantageous.

4. Conclusions and Suggestions

The results of the alternative solutions and the selection of the B are in harmony with the willingness of the respondents (questionnaire) for a better approach to the area, with smaller costs and effects on the forest landscape. A small difference on the potential of absorption from the natural environment is shown by alternative A.

The impacts from the forest road are not considered significant. The most significant effect is upon the forest landscape-physiognomy of the area, as a result of the removal of flora and the surface of slopes.

Taking suitable measures such as the avoidance of unnecessary earth fills and large axial gradients, the construction of ditches and draining gutters as well as the use of machines friendly to the environment (e.g. excavators) will reduce the impacts on the natural resources and will increase the absorption of the proposed alternative solution.

It is very useful to have alternative road construction solutions clearly mapped out for comparison before road construction begins. These solutions should be based on the newest planning technique and according to the aims of forest infrastructure development, the terrain conditions and the protection of the forest ecosystem.

In sensitive ecological systems such as Mediterranean forest areas it is very important, from a technical and an economic design perspective, to have a realistic concept, within the framework of an environmental impact assessment (E.I.A.) or better ESCs (Environmental Standard Commitments).

It will very practical and useful for the assessment by the ESCs to have a list of serviceable criteria, and their weights to evaluate the absorption of road construction in order to make a profile for each forest road.

Multi-criteria evaluation (MCE) analysis (the implementation of decision-making rules to identify and enable the combination of many criteria, in the form of GIS layers, into a single map) and Geographic Information Systems (GIS) are two examples of tools that aid in the development of geographic data and maps for different purposes, such as conserving land for forestry uses and the quantitative and qualitative evaluation of the impact of the forest road on the environment.

References

1. Abeeg B., 1983. Einfluss der Wegedichte auf Rückeverfühlen und Rückedistanzenim Bergwald. In: S.Z.F., Zürich, vol. 134(8), pp. 621-628.

2. Doukas A.-K., Drosos V.C., 2013. Forest road construction and natural environment. Tziolas Publications, Thessaloniki, Greece, 420 p.
3. Drosos V.C., Eskioglou P., Karagiannis E. et al., 2003. Environment Impact Assessment (E.I.A.) for the evaluation of forest roads in mountainous conditions. In: Proceedings of the International Conference Austro 2003: High Tech Forest Operations for Mountainous Terrain, 5-9 October, 2003, Schlaegl, Austria.
4. Drosos V.C., Liampas S.-A., Skondras N. et al., 2014. The development of a multi-criteria decision support system to approach forest opening-up assessment. In: Proceedings of the 1st International GEOMAPPLICA Conference, 08-11 September, 2014, Skiathos, Greece, pp. 314-322.
5. Drosos V.C., Malesios C., 2011. Management and improvement of a forest road network. In: Proceedings of the 4th International Scientific Conference 2011, 07-10 September, 2011, Prague, Czech Republic, Section 2, pp. 426-433.
6. Giannoulas V., 2001. Forest opening-up with modern machinery. Technico-econmic, enviromental effects. Ph.D. Thesis, Aristotle Univ. of Thessaloniki.
7. Kroth W., 1973. Entscheidungsgrundlagen Bei Walderschliessunginvestionen. In: Fw. Cbl. Jg. , vol. 87(4), pp. 237-248.
8. Law 1650, 1986. Government Gazette GG A-160 / 16-10-1986. For the protection of the environment.
9. Law 743, 1977. Government Gazette GG A-319 / 17.10.1977. On the protection of the marine environment and regulation of related issues.
10. Zavadskas E.K., Pamučar D., Stević Ž. et al., 2020. Multi-criteria decision-making techniques for improvement sustainability engineering processes. In: Symmetry, vol. 2(6), article no. 986.

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM "*FOREST AND SUSTAINABLE DEVELOPMENT*"
9TH EDITION, 16TH OF OCTOBER 2020, BRASOV, ROMANIA

SPATIAL PLANNING INDICATORS FOR THE SUSTAINABLE DEVELOPMENT OF MOUNTAINOUS AREAS

Vasileios C. DROSOS[1 *]   Georgios TASIONAS[1]
Ioannis KOUKOULOS[1]   Iordanis KASAPIDIS[1]
Vasileios STAVRIDIS[1]   Ioannis SISMANIDIS[2]

Abstract: *The development of mountainous areas is linked with human interventions on them since any kind of economic development is usually characterized by unfavorable environmental impacts. However, there is an inherent paradox, namely the human intervention degrades the natural and built-up environment, which at the same time constitutes the raw material for its development.*

The objective of this paper is the specification of measurable criteria-indicators for an integrated strategy of sustainable development of mountainous regions. A basic and necessary condition for achieving this objective is the rational development in all three sectors of the mountain economy, which are forest - agriculture, livestock and tourism, that can evolve dynamically and plan various activities and functions. This requires a regional approach to nature conservation, spatial planning and water management leading to certified objective decisions in order to draw out proposals regarding specialized production activities, according to a proper typology that characterizes the differentiation of regional problems, needs and perspectives.

The concentration of private and public investments in these areas target to environmental protections and the economic revitalization of forestry, agriculture, tourism, cultural heritage and the existing network of villages, as well as to a total environmental upgrading.

All these can be achieved by improving the transportation system and the access conditions in the mountainous areas, as well as with the introduction of new technology and information systems can be addressed the problems of isolation of these areas. Total environmental upgrading of mountainous areas can be achieved by the protection and upgrading of the natural ecosystems, the forest landscapes, and their natural and cultural resources.

[1] Forestry & Management of the Environment and Natural Resources, Democritus University of Thrace, Ath. Pantazidou 193 Str., Orestiada, GR 68200, Greece;
[2] Secondary Education, Directorate of Secondary Education, GR 66100 Drama, Greece;
Correspondence: Vasileios C. Drosos; email: vdrosos@fmenr.duth.gr.

Key words: *Zoning, exploitation, forest - agriculture, livestock, tourism, rational development.*

1. Introduction

The concept of sustainability comes from forest terminology and in the literature the Saxon forester H. von Karlovic is considered to be the inventor of the concept, who in 1713 first used the expression "sustainable" in the following phrase: "*Art, science and their status for the country is based on the ability to maintain and develop wood capital in such a way as to achieve a stable, permanent and sustainable exploitation, because this is a necessary condition without which the country cannot exist*". The concept appears as an adjective and emphasizes the duration of an effect or an influence, while the word "sustainable" did not pre-exist in the dialect of German-speaking countries.

The development of mountainous areas is linked with human interventions since any kind of economic development is usually characterized by unfavorable environmental impacts.

Local development studies particularly of mountainous forest regions are limited and rarely integrated in the frames of a zoning that safeguards the space of vital importance with the help of an organic and flexible plan of land use [3].

During the past years due to the reckless and catastrophic for the environment linear economical "developmental" activity, dramatic significance facts for humanity were occurred. The perception that development will be either integrated, namely economic, social, technical/technological, political, and cultural, or otherwise there can be no development, is becoming more and more popular. Always in harmonious interaction and respect with the natural and cultural environment, whose part is also man [9].

There are cases where the term of the Integrated Development is used on schemes or programs (e.g. Integrated Development of the rural regions). It is of vital importance and requires the harmonious collaboration amongst the newest scientific and technological potentialities from one side and the virtual potentialities and restrictions from the other, although, the physical and socioeconomic reality on local, peripheral, national and global level has not yet been fully understood. The strategies for "development" that are being applied, as we can also see from the strategy applied on the fields of agriculture, stockbreeding and forestry, having as "standard" (or pretext) the sustainable development, characterize a development with ambiguous as well as documented dubious context [7, 8, 10]. In fact, encouraging classical sectoral development, with the aim of further developing competitiveness and economic growth, mainly serving the interests and needs of the modern human.

According to dictionaries, indicators are used to show the level or state of something. Therefore, they are very important tools to measure the success of a process.

The main difficulties to overcome in the identification process of indicators useful to evaluate the effectiveness of the sustainable development strategies in mountainous areas are the lack of monitoring systems and of the availability of data on local level.

On the mountain, each micro-region can choose their own indicators that will reflect the specific local conditions and their priorities and objectives. Before developing a set of effectiveness indicators, it is necessary to define the measures for achieving the objectives. Particularly important is to define the "measure units" which indicate the state of objectives or other monitored phenomena development, and to fix the target value of the indicators. On the other hand, in some regions, it may be difficult to raise the necessary information, due to a lack of available data. An additional difficulty is that some very important activities could even show their positive results not in a short-term view, but in longer perspective [6].

Effectiveness indicators should be relevant, easy to understand, reliable and based on accessible data.

The aim of this paper is the specification of measurable criteria-indicators as concern the opening up of a mountainous forest area for an integrated strategic of sustainable development of mountainous regions.

2. Material and Methods

2.1. Research Areas

The quality of the opening up efficiency was investigated in two characteristic mountain complexes.

The Oligyrtos (1935 m) mountain is laid in the west Argolida Prefecture which belongs to Peloponnesus region in Greece. Major peaks are Skiathis (1180 meters), Farmakas (1616 m) and Megalovouni (1273 m).

The mountain of Farmakas (Longitude: 22^{o} 30′ 10′′, Latitude: 37^{o} 46′ 20′′) - 1616 meters in altitude - dominates the north-western edge of Argolida Prefecture. Farmakas is a majestic mountain, overgrown with trees (especially fir trees), which owes its name to the many therapeutic herbs (medicines) that grow on the slopes and diligently collecting the old years, to use for each disease (Figure 1).

In the eastern ends of Farmakas, the neck forming with the Megalovouni, placed the great city of antiquity Orneai, whom Homer mentions as participating in the campaign against Troy, led by Menesthea. The city bore the name of the housing, Ornea, son of Erechthea and Praxitheas, descendants of Athena. In Table 1 we can see the land uses for the area.

Table 1

Land uses in 2009

Land use	Extent [ha]	Percentage [%]
Forestlands	1878.9	62.45
Partly forestlands	780.4	25.94
Grasslands	302.3	10.04
Agricultural lands	47.3	1.57
Grand total	3008.9	100

The second research area is the Pinakates - Milies - Vyzitsa of Pelion of Magnesia Prefecture (Figure 1). Showing almost all aspects on the horizon, with the predominant S - SW, N - NW and E and the altitude ranges from 0-1466 meters (top Tsakos). The slopes are on average between 10-70%. The predominant species are sweet chestnut, common walnut tree, forest beech and downy oak.

2.2. Methodology

The urgent goal of spatial planning of forest areas should be to ensure, within an organic and flexible land use plan of the living space for [2]:

a. The productive land;
b. The hydrological network;
c. Forests and forest areas;
d. The traditional-cultural heritage;
e. The development of the area in the context of maintaining compatibility with the environment.

Fig. 1. *Research areas*

Therefore, the spatial development plan of forest areas must contain the phases from Figure 2.

The rational and sustainable development of the mountainous areas goes through the spatial planning and mainly concerns in the mountainous forest areas the forest roads' network (Forest Opening Up).

As a concern of the opening up [4], the overall strategic planning of an integrated opening up of a forest area is affected and changed spatio-temporally by forest-ecological factors and the needs that the opening up of the forest is required to serve, such as shown in Table 2.

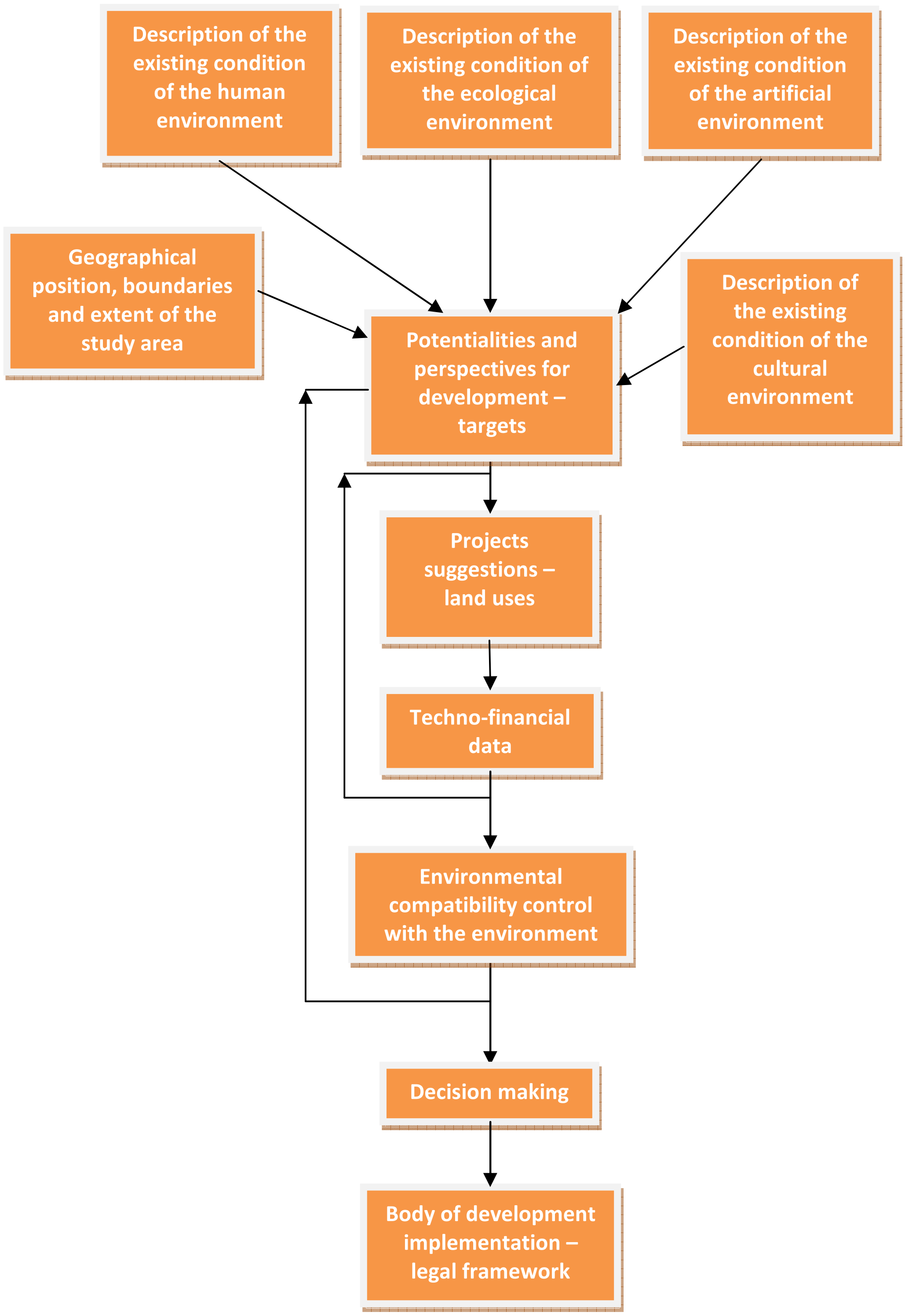


Fig. 2. *Spatial planning diagram of forest areas*

The indicators that were used to the opening up of a forest are [4, 5]:

- *Road density* is the ratio of the length of the region's total road network to the region's land area; the road network includes all roads in the area: main or national roads, secondary or regional roads, and other forest and rural roads [m/ha];
- *Road spacing* is the ratio of 10,000 to road density [m];
- *Skidding distance* is the ratio of 2,500 to road density [m];
- *The opening up percentage;* this indicator is the percentage [%] of the area in relation to the total area of the forest opened by the forest roads network; the opening up percentage is substantially affected by the terrain configuration; in Table 3 is shown a classification of opening up percentages into groups [1].

Table 2

Needs to be served by forest opening up

A / a	Needs to be served by Forest Opening Up
1	The forest management form
2	The topographic morphology of the forest area
3	The density and allocation of vegetation
4	The quantity and quality of woody capital
5	The transport of staff
6	The moving of timber (skidding-transportation of timber)
7	The requirements of forestry

Table 3

Forest opening up percentage classification

A / a	Opening up percentage	Opening up condition
1	Up to 65%	Unfavorable
2	Up to 70%	Partly favorable
3	Up to 75%	Favorable
4	Up to 80%	Very favorable
5	Greater than 80%	Unusually favorable

3. Results and Discussion

The indicators which characterize the opening up of a forest are:

1. The road density;
2. The road spacing;
3. The skidding distance;
4. The opening up percentage.

These indicators are also expressed with characteristic numbers that show the magnitude of their impact on the forest opening up, while the last indicator is also expressed cartographically. Essentially, the last indicator characterizes the quality of the spatial distribution of the roads and thus is the most important indicator of the efficiency of the network in a forest complex.

In the theoretical model with parallel forest roads with equal distances from each other, the opening up percentage takes the maximum value E = 100%, but in practice in mountainous areas, it is impossible to happen.

Below are shown in the two mountainous areas with different management data, the opening up percentage and therefore the quality of the opening up efficiency.

According to the Table 2 the opening up of Farmakas (Figure 3) is unfavorable as the opening up percentage is less than 65%. Construction of tractor roads is needed up to a total road density (Roads and tractor roads) of 50 m/ha, with a road distance of 10000/50 = 200 meters, in order to achieve the mechanization of skidding. This would mean a burden on the environment.

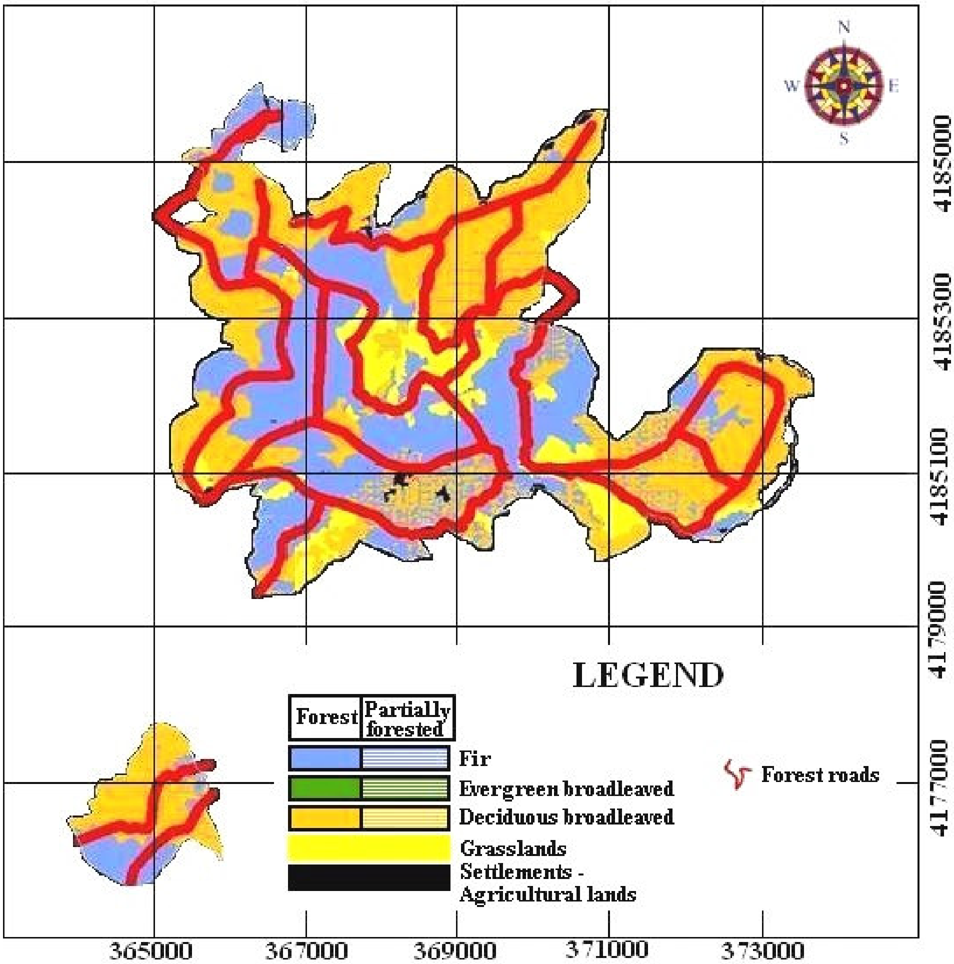


Fig. 3. *Map of opening up of Farmakas*

Regarding the spatial distribution of the road network, this is satisfactory because:

- With the optimum road distance of 800 m (300 uphill and 500 downhill) a forest protection percentage of 90.00% was calculated (Figure 4);
- The existing road density (D_{ex} = 46.50m/h) exceeds the limit of 12.5 m / ha and the road distance is less than 800m. So, the spatial distribution exceeds the fire protection target, with local problems in the NW of the complex, as shown in Figure 4.

It is observed that with the development of the indicators related to the opening, the goal can be set up, and one can think on how to measure whether the goal was achieved after the activity or the implementation of the project or not.

The indicators should reflect public, economic and sociological issues / activities and their real impact.

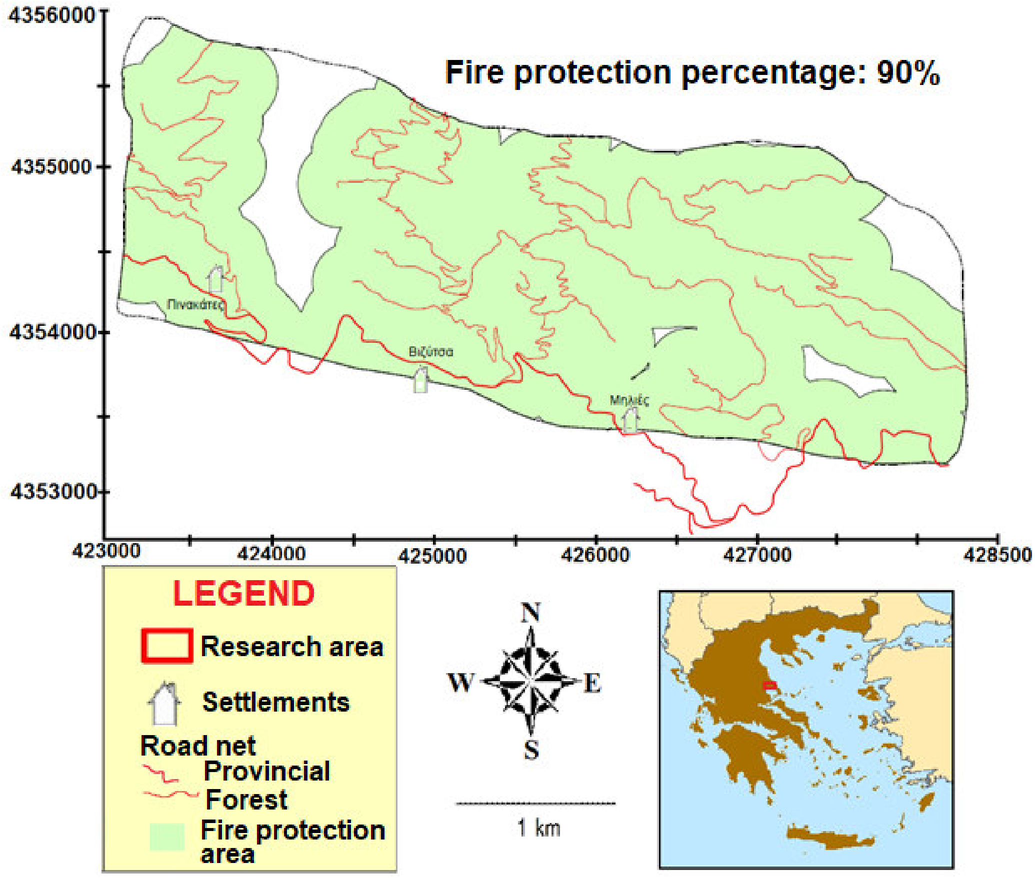


Fig. 4. *Map of Pinakates – Milies – Vyzits a opening up and fire protection percentage*

5. Conclusions

These indicators were selected, in order to have the best results based on the strategic objectives which were time set up in relation to the monitoring of networks of residential development and the singularity of mountainous forest areas.

Elements of paramount or crucial importance that can lead to safe conclusions for investment decision-making in mountainous areas are spatial planning and forest maps in combination with EIAs for the protection of the natural environment. The criteria-indicators, however, must be measurable and lead to certified objective decisions. The indicators use measurable quantities that give a measure of the state of the environmental, social and developmental characteristics of the residential systems that contribute to the creation problems to the quality of life in the local community. They include traditional environmental variables but also other that are not directly related to the environment.

The development of local sustainability indicators for mountainous areas, with the goal of keeping the rational support of a spatial planning in decision-making process, is important and necessary. Necessary conditions for the prosperity of mountainous areas remain the broad social acceptance of the idea of sustainability and the need to accelerate progress towards sustainable development. This is helped by the political leadership guidelines and the effectiveness and efficiency in dealing with the needs of the mountainous population.

It is observed that with the development of the indicators related to the opening, the goal can be easily set up, one can think on how to measure whether the goal was achieved after the implementation of the project or not. The indicators should reflect public, economic and sociological issues / activities and their real impact.

The creation of an Observatory of Mountainous areas Development (OMD) covering Greece, will contribute to the sound mapping of the identity of Greek mountainous residential system. Also, it will help the creation of a standard framework for the monitoring indicators of mountainous residential system's development.

The renewal of the components of OUD contributes decisively to update and support policies on matters which are selected as critical to a residential area. Therefore, national infrastructure needs updated geospatial information.

A standard pattern of the opening up of forest areas is impossible, since each forest area is something special that requires special design and handling. The techno-economic study of the opening up of each forest area is achieved after a thorough study of traffic, soil and climatic, forest-economic and ecological conditions of the region. The assessment of the indicators with the key factor reflected by the opening up percentage is necessary for the evaluation of spatial distribution of forest roads.

The opening up percentage is the most important indicator of forest roads planning and the sustainable development of mountain regions should take into account this indicator.

References

1. Backmund F., 1966. Kennzahlen für den Grad der Erschließung von Forstbetrieben Durch autofahrbareWege. In: Forstwissenschaftliches Zentralblatt, vol. 85(11/12), pp. 342-354.
2. Doukas A-K., 2004. Forest constructions and natural environment. Giaxoudis Publishing, Thessaloniki, Greece.
3. Drosos V.K., 2009. Environmental improvement of forest road. In: Proceedings of the Second Pan-Hellenic Conference of Urban Planning and Regional Development: "Management and Protection of the Environment", Volos, Greece, pp. 1025-1032.
4. Drosos V.K., Karagiannis E., Doucas K.-A.G., 2013. Forest Opening Up. Skidding and Transportation of Forest Products. Tziolas Publishing, Greece.
5. Lotfalian M., Zadeh E.H., Hosseini S.A., 2011. Calculating the correction factor of skidding distance based on forest road network. In: Journal of Forest Science, vol. 57(11), pp. 467-471.
6. Niccolini F., Plotino M.F., Marzo D., 2014. Information, training and awareness raising strategies in mountain regions of south-east Europe. Final report of project title: "A sustainable development model for green mountain areas".
7. Rist G., 1997. The History of Development. Zed books, London and New York, UK.
8. Rokos D., 1980. Cadastre and Redistribution – Land Policy. Mavromatis Publishing, Athens, Greece.
9. Rokos D., 1998. The interdisciplinarity of the integrated approach of the natural and socioeconomic reality. In: Philosophy, Science and Politics (editor P. Noutsos). Publising Typothito – G. Dardanos, pp. 403-437.
10. Schuurman F.J., 1996. Beyond the Impasse. Zed books, London and N. Jersey, UK.

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM "*FOREST AND SUSTAINABLE DEVELOPMENT*"
9TH EDITION, 16TH OF OCTOBER 2020, BRASOV, ROMANIA

GPS PRECISION IN FOREST ENVIRONMENTS

Constantin I. GRESITA[1]

Abstract: *Topographic measurements performed with GPS technology became frequently used in the recent decades. However, this technology has its limitations when it comes to the obstacles between the receiver and the signal received from the satellite. The errors that different obstacles may produce have different values. A special case is that of the errors we encounter for GPS measurements in the forest environment. The crown of broadleaved trees looks different throughout the year depending on the season. At the same time the measurement accuracy may be different depending on the method used. The present paper aims to determine the accuracy under the crown of broadleaved tree species within and outside the growing season using different measurement methods. The differences obtained by the two methods of static determination and RTK were between 0.4 m and 2 m, respectively, compared to the real coordinates determined by classical methods.*

Key words: *GPS, accuracy, forest, measurements.*

1. Introduction

The use of GPS technology was a revolutionary moment in determining the coordinates of a point. Before that moment the best technique for worldwide positioning were using astronomical technique with their limitation of accuracy while after on the satellite base Global Navigation Satellite System (GNSS) technology has been played as remarkable tool for positioning and mapping with high accuracy can be achieved in the easiest way [1, 2, 6, 10]. Being a relatively easy to use technology, there is a tendency to use it as much as possible, taking advantage of the advantages it offers, mainly in terms of the speed with which the determinations are made. However, this technology also has its limitations, being influenced by the environment and being very sensitive to obstacles that obstruct the visibility to satellites.

The GNSS indeed become a revolution in positioning on the 20th century. Nevertheless, few limitations are still recognized such as the capability of positioning under heavy satellite obstructions (e.g. in dense urban area, and in canopy area like forest), especially for the Real Time Kinematic (RTK) method (Figure 1).Obstruction will disturb the signal connection and produce cycle slip, and un-favor fixing the ambiguity [4, 8]. As

[1] Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and forest engineering, Transilvania University of Brasov, Șirul Beethoven no. 1, 500133, Brasov, Romania;
Correspondence: Constantin Irinel Gresita; email: irinel_g@unitbv.ro.

for the RTK, in many cases it would give autonomous result, float solution, hardy waiting for resolved ambiguity, and or in some cases given the possibility of fixing to the wrong integer. Not to mention if we set up longer baseline, therefore the degradation in accuracy will more significant. This is the new challenge to be solved, since many applications are dealing with situation of positioning under heavy satellite obstruction such as for forest boundary surveys, rural urban parcel measurements, in between high rise building measurements, etc. Theoretically the availability of more satellites, the existence of another phase signal, and or stronger signal may answer the limitation [3].

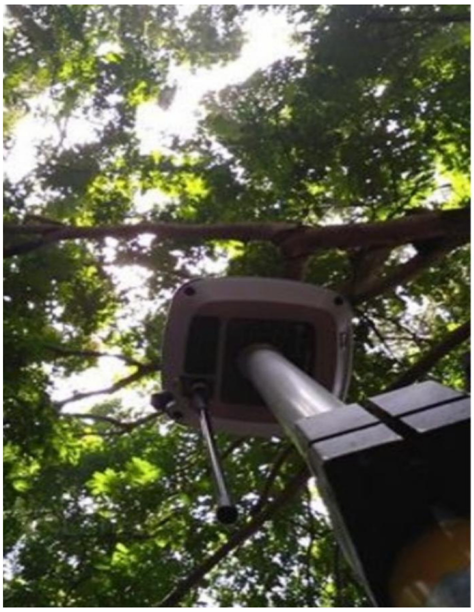


Fig. 1. *Satellites obstructions [3]*

The purpose of this research is to determine the accuracy of determining coordinates using the GPS positioning technique on land covered with forest vegetation and whether this technology can be satisfactory for its use in cadastral works.

2. Study Area

The studied area is at an altitude of approximately 160-170 m and is part of the Cosacu forest body, being at the intersection of compartment6A, 7A and 8C, UP II Bucovat, OS Craiova, Romania (Lat: 44.272586, Lon: 23.730904) where there are mixed oak forest consisting of *Quercus frainett*o [Ten.] and *Quercus cerris* [L.], having an age of approximately 70 years, with a consistency of 0.7, coming from shoots, having a medium productivity (Figure 2).

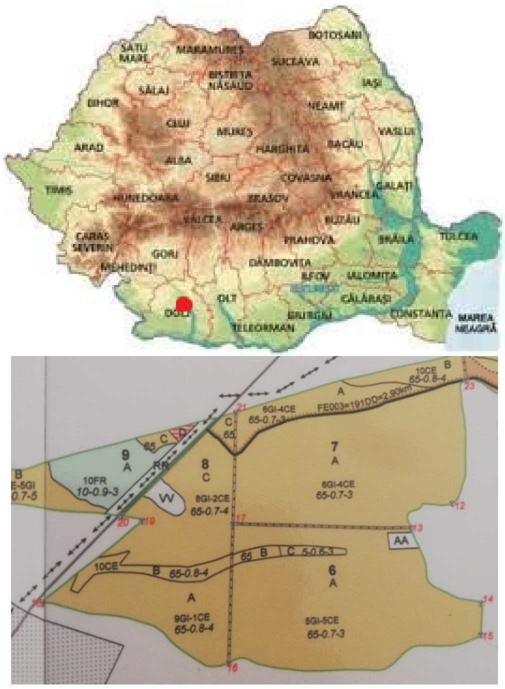


Fig. 2. *Study area*

3. Materials and Methods

This study is the first part of a larger one in several areas with different forest vegetation and landforms. In the study area a number of 3 landmarks located along a forest road in a deciduous forest were determined by 3 different methods.

In order to study the influence of the tree crown on the accuracy of the determinations depending on the degree of obstruction of the visibility to the satellites in different conditions. The determinations were made in winter, when there are no leaves in the crown of the trees as well as in summer when the coverage of the branches with leaves is maximum.

In order to determine the reference coordinates of the three points, they were determined by the classical method that is not influenced by the covering of the sky with obstacles. For this, a Leica TS 02 total station was used with the help of which a traverse supported on points determined with GPS technology was performed, points located at a sufficient distance so that the accuracy is not influenced by the presence of the forest. Thus, the coordinates with which we will compare the results obtained later were determined (Table 1).

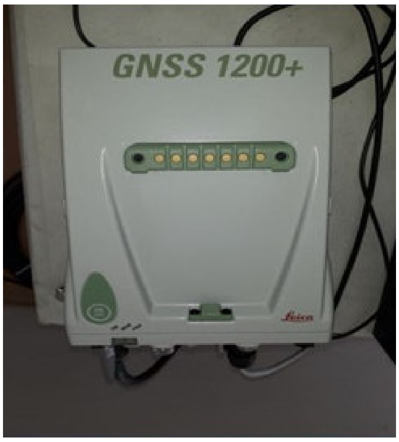
Table 1. *The points coordinates*

Point	X(m)	Y(m)	Z(m)
4	308719,619	398743,475	162,965
5	308945,584	398754,694	162,729
6	309095,136	398761,626	162,861

The points (Figure 3) were materialized on a forest road and determinations were made both in winter (without leaves) and in summer (with leaves). The aim was to determine whether in particular RTK technology can be used to pick up details inside the forest such as plot boundaries, forest roads, etc. with satisfactory accuracy for cadastral works.

Fig.3. *GPS on points*

For the determination of each of the three points, a determination was performed by static method with duration of 30 min and two RTK determinations of 20 sec each. The base station from the national ROMPOS system located at a distance of around 7 km was used as a reference station.



a)

b)

Fig. 4. *The GNSS technology used in research: a) the GNSS receiver Leica 1200+; b) reference station CRA*

4. Results and Discussion

GPS receivers determine their distance from each visible satellite by comparing the satellite's clock time with the receiver's clock time. If the signal from a satellite is blocked, the receiver will choose another satellite, leading to a position calculated from a poorer satellite configuration and possibly containing more position error [6]. The accuracy of a GPS position depends on several components, one of which is the geometry of the satellites with respect the receiver [7]. Forest vegetation can block the signal from GPS satellites, causing the receiver to use a less than ideal satellite configuration. After the winter, when are no leaves in the trees, the measurements were processed by using the specialized software of the GPS receiver manufacturer, the following values were obtained (Table 2).

In summer, when the trees have a crown full of leaves were obtained the values presented in Table 3.

For a better visualization of the results they were represented graphically (Figures 4 to 6).

Using the static method and with a relatively long stationary time on the point, acceptable results were obtained only in winter when there are no leaves in the trees, but the method is not efficient and is time consuming. The static method could be used in winter in forests with species that lose their leaves but with great caution and only for determining fixed points with double checking on at least two reference stations. In this case a minimum four points must be determined and can possibly be used as fix points for a closed traverse.

Table 2

Values obtained for the measurements made after winter

Method	Coordinates			Differences (m)		
	X (m)	Y(m)	Z(m)	Δx	Δy	Δz
Point 4						
reference	308719,619	398743,475	162,965			
rtk1	308717,612	398741,135	166,560	2,01	2,34	-3,60
rtk2	308721,295	398743,215	162,308	-1,68	0,26	0,66
static	308719,792	398743,512	162,930	-0,17	-0,04	0,03
Point 5						
reference	308945,584	398754,694	162,729			
rtk1	308945,239	398756,787	167,620	0,34	-2,09	-4,89
rtk2	308945,264	398756,930	166,615	0,32	-2,24	-3,89
static	308945,670	398754,714	162,696	-0,09	-0,02	0,03
Point 6						
reference	309095,136	398761,626	162,861			
rtk1	309096,040	398762,215	167,690	-0,90	-0,59	-4,83
rtk2	309095,286	398762,130	163,800	-0,15	-0,50	-0,94
static	309095,215	398761,686	162,800	-0,08	-0,06	0,06

Table 3

Values obtained for the measurements made in summer

Method	Coordinates			Differences (m)		
	X (m)	Y(m)	Z(m)	Δx	Δy	Δz
Point 4						
reference	308719,619	398743,475	162,965			
rtk1	308720,299	398743,487	163,770	-0,680	-0,012	-0,805
rtk2	308723,360	398742,768	166,251	-3,741	0,707	-3,286
static	308719,939	398743,833	163,869	-0,320	-0,358	-0,904
Point 5						
reference	308945,584	398754,694	162,729			
rtk1	308946,255	398755,111	163,550	-0,671	-0,417	-0,821
rtk2	308946,952	398755,550	164,700	-1,368	-0,856	-1,971
static	308945,961	398754,966	163,712	-0,377	-0,272	-0,983
Point 6						
reference	309095,136	398761,626	162,861			
rtk1	309093,831	398760,910	164,352	1,305	0,716	-1,491
rtk2	309092,372	398761,513	162,929	2,764	0,113	-0,068
static	309095,556	398761,952	163,961	-0,420	-0,326	-1,100

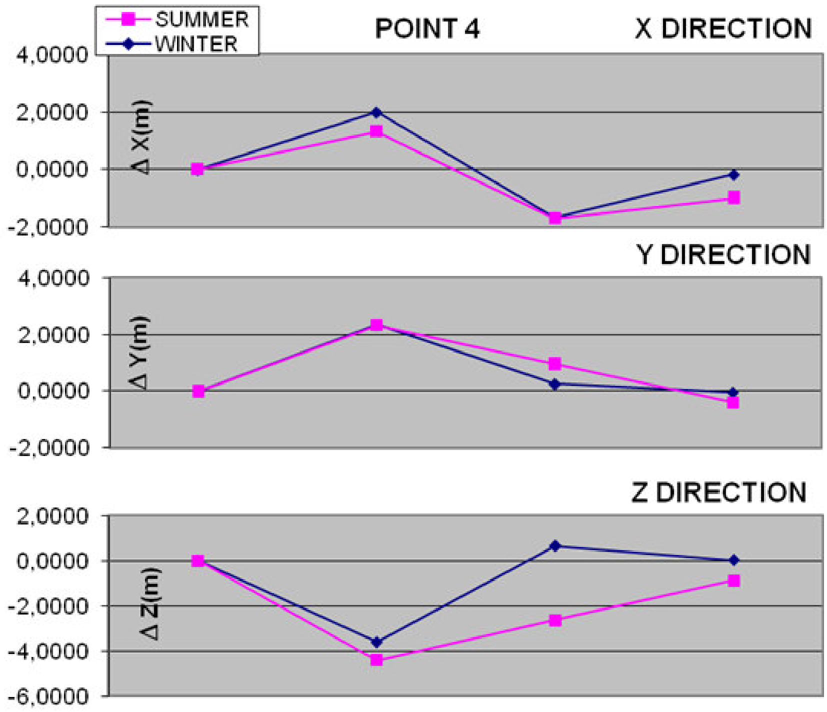


Fig. 5. *Differences obtained for point 4*

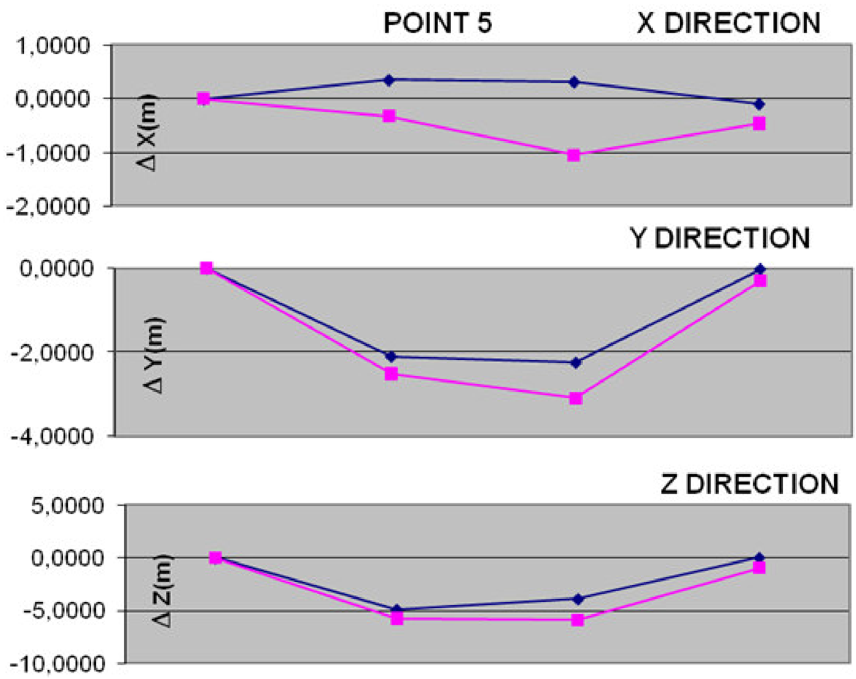


Fig. 6. *Differences obtained for point 5*

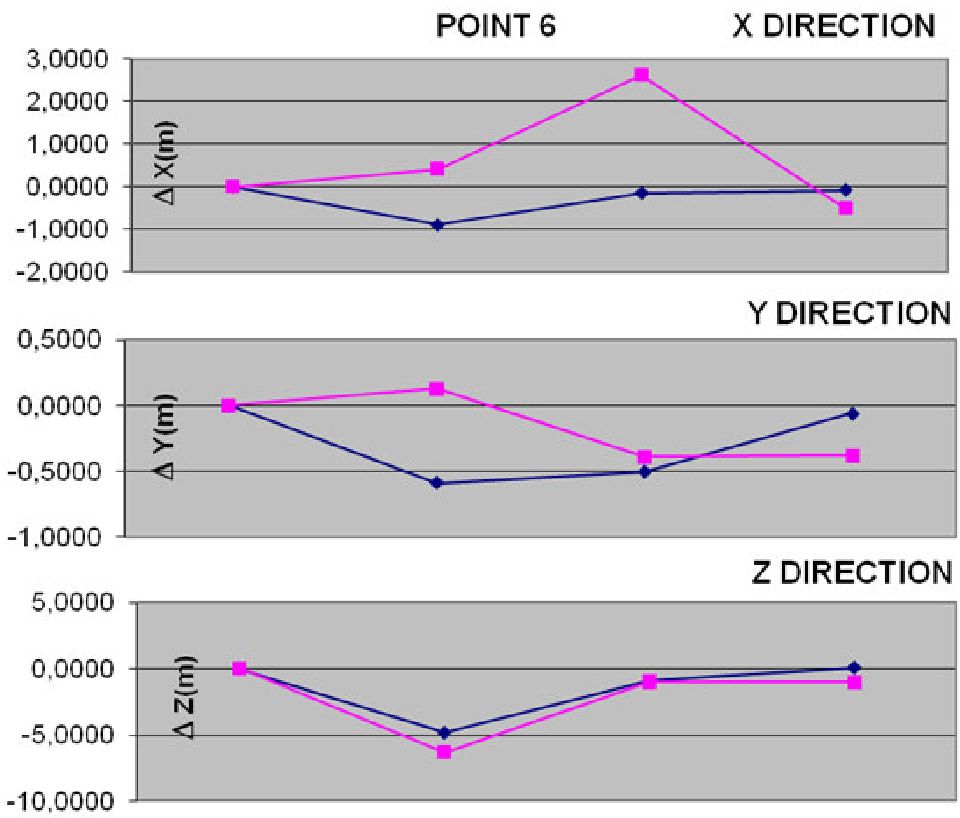


Fig. 7. *Differences obtained for point 6*

Similar future analysis might instead use values calculated of tolerable error as a threshold for optimum identification, as an alternative methodology that may provide results focused on the objectives of each survey. Some authors have calculated such admissible errors, which might depend on the forest variables themselves [9] or the remote sensing technique [5].

5. Conclusions

The differences obtained by the two methods of static determination and RTK were around 0.4 m and 2 m respectively compared to the real coordinates determined by classical methods.

The precision of determining the coordinates of a point in the forest using GPS RTK technology is not sufficient and does not fall within the tolerances provided by the cadastral legislation for determining the boundaries of the plots.

The static method does not provide the necessary accuracy for determining fix points even with long-term stationary time in summer when are leaves in the tree.

The absence of leaves did not significantly influence the accuracy obtained using RTK method, and we can conclude that the main obstacle that negatively influences the measurements is the branches themselves. Depending on location of branches, the arrangements (the form of crown, the density of branches), the thickness of branches depends on tree species from the study area another results from different type of forest trees, can be different.

References

1. Abidin H.Z., 1999. Penentuan Posisi dengan GPS dan Aplikasinya. PT. Pradnya Paramita, Jakarta.
2. Abidin H.Z., 2001. Geodesi Satelit. Departemen Teknik Geodesi ITB, PT. Pradnya Paramita, Jakarta.
3. Andreas H., Abidin H.Z., Anggreni Sarsito D. et al., 2019. Study the capabilities of RTK Multi GNSS under forest canopy in regions of Indonesia. In: E3S Web of Conferences – ISGNSS 2018, vol. 94, 01021.
4. D'Eon S.P., 1996. Forest canopy interference with GPS signals at two antenna heights. In: Northern Journal of Applied Forestry, vol. 13(2), pp. 89-91.
5. Gobakken T., Naesset E., 2009. Assessing effects of positioning errors and sample plot size on biophysical stand properties derived from airborne laser scanner data. In: Canadian Journal of Forest Research, vol. 39(5) pp. 1036-1052.
6. Hofmann-Wellenhof B., Lichtenegger H., Walse E., 2007. GNSS Global Navigation Satellite Systems: GPS, GLONASS, Galileo, and More. Springer Verlag, Wien, Austria.
7. Hurn J., 1989. GPS: A guide to the next utility. Trimble Navigation Ltd. Sunnyvale, CA. 76p.
8. Leick A., 2004. GPS satellite surveying. 3rd Ed. Wiley, New York.
9. Mauro F., Valbuena R., García A. et al., 2009. GPS admissible errors in positioning inventory plots for Forest Structure Studies. In: Proceeding of IUFRO, Division 4 meeting. Extending Forest Inventory and Monitoring over Space and Time. 19-21 May, Quebec City, Canada.
10. Seeber G., 1993. Satellite Geodesy: foundation, method, and applications. Walter de Gruyter, Berlin-New York, C7.

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM "*FOREST AND SUSTAINABLE DEVELOPMENT*"
9TH EDITION, 16TH OF OCTOBER 2020, BRASOV, ROMANIA

MEASURING THE EFFECT OF FOREST LAND CONSOLIDATION IN BULGARIA. CASE STUDY OF NORTH-WESTERN STATE ENTERPRISE

Nikolay NEYKOV[1] **Petar ANTOV**[2] **Ilko DOBRICHOV**[3]
Aureliu F. HALALISAN[4] **Emil KITCHOUKOV**[1]

Abstract: *Land consolidation in forest areas is a problem that has been sought in Bulgaria in recent years. This is a problem in all forests where ownership is distributed between the state, municipalities and private owners. Timber harvesting and exportation is much easier and cheaper when access is easier. This article summarizes the main results of forest land consolidation, highlighting the leading effects of the land consolidation campaign in Bulgarian Forestry. The purpose of the study is to calculate some basic outcomes of consolidation that allow determining the economic effectiveness of it. The study showed that at this stage the goals set by the state for achieving forest consolidation have been partially achieved. The effects are mainly on improving the management of forest areas, especially in the part of those that are not aimed at harvesting and profits. The results for the local communities are not satisfactory and solutions in this direction must be sought. Current paper is the first step of developing an optimization model in purpose of supporting the forestry units in Bulgaria and in other countries which have undertaken such an uneasy task.*

Key words: *forest, land, consolidation, measurement, management, methodology.*

1. Introduction

Bulgarian forestry is a state structure functioning as a private corporate organization. The whole sector is divided into six companies. They finance their own activities. Decisions for the development of the sector are entrusted to managers. Forest management and timber use are activities that require positive economic

[1] Faculty of Business Management, University of Forestry, Sofia, Bulgaria;
[2] Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria;
[3] Faculty of Forestry, University of Forestry, Sofia, Bulgaria;
[4] Faculty of Silviculture and forest engineering, Transylvania University of Brasov, Romania;
Correspondence: Nikolay Neykov< e-mail: nneykov@ltu.bg.

efficiency. This is the reason why management teams seek the development of enterprises through different solutions. The forest land consolidation can be considered as one of them. According to Demetriou [2] the land consolidation is the one of the primary and most effective land management instruments for rural sustainable development. The main goal of forest land consolidation is often to improve the usability of the area for commercial forestry, but depending on the country and the location, environmental issues may also be important [8]. The increasing fragmentation of privately-owned forest land represents is a main challenge for the future supply of wood raw material in the forest-based sector [7]. In this context, land consolidation means a comprehensive reallocation procedure of a rural area consisting of fragmented agricultural or forest holdings or their parts [13].

To date, there is no clearly formulated methodology for assessing the effects of forest land consolidation in the Bulgarian forest sector. The consolidation procedures carried out so far by the Bulgarian forest authorities aimed at achieving greater efficiency for timber harvesting and other objectives with non-economic effects. The main purpose of the consolidation process, officially published was to foster the steering of the forests mainly with protective functions. The so-called first stage in 2016 was a kind of experiment with consolidation of forest areas. Its combined effect is still not clear neither for the authorities nor for the academics. In some bureaucratic way the Ministry of Agriculture, Food and Forestry decided to repeat the "experiment". At present, the so-called second stage of consolidation, for which 1,000,000 Euro has been allocated, has already been finished. The previous stage, carried out in 2016, was in amount of 350,000 Euro.The consolidation process was initiated with an "Order of the Minister of Agriculture, Food and Forestry". The Order covered all six state forest enterprises in the country. It was based on the Law on Forests under art. 163 [14]. Following the publication of the Minister's Order, the rules for consolidation were published. They observed the general algorithm/procedure of land consolidation campaign, but with some specific requirements. Only land properties in forest territories, owned by individuals, with an area of a separate property between 1 and 50 decares [15], are purchased with the funds (which have been subsidised) of the State Enterprise. Through this main requirement the state intended to spread the effect to as more as possible individuals in the territory of the state enterprise. In fact, the consolidation investigated here is the first of the three campaigns. The beginning of the second one was in 2019, but results were partially published until 2021, so it is still under assessment. All the procedures during the three campaigns are almost identical and the same in each state enterprise. They included:

- Introduction. The public was informed about the upcoming campaign. Information was provided on the size of the properties and the features they must have. People from local communities could apply;
- General requirements for the documents and application procedure. One of the most important elements of the procedure was the requirements to the property

documents and their forest assessment characteristics. The proximity typical of consolidation with state forest parcels was sought;

- Criteria, evaluation and ranking. In fact, the most of the criteria were covered under the preliminary stage in documents requirements. The main criterion was the difference between the price of the parcel given by its owner and the expert evaluation – the greater the evaluation, the greater chances State Enterprise to purchase the parcel;
- Purchase of forest parcels. The parcels had been chosen after the selection procedure was purchased by the enterprise.

The procedure did not include any evaluation of the effect. Even for the enterprise itself. It was not clear and still it is not whether the procedures caused any short-term effects or not. These campaigns included interference in rural regions. The North Western State Enterprise (NWSE) is fourth by size with forests area of 512022 ha of total 1961426 ha. On its territory are situated many of the protected areas in the Old Mountain region. In the same time, it covers the poorest region in the EU – North-Western region in Bulgaria. By these aspects the assessment of the campaign not only by the criteria in the Minister's Order would reveal the potential of consolidation like a tool for improving the sustainability of vulnerable regions like the North Western in Bulgaria. The purpose of the present study is, based on the available information, to make a summary assessment of the effect of the consolidation carried out on the investigated enterprise and on the region in which it is located. The NWSE continued to consolidate parcels after the campaign with its own financial sources. This is the reason to be topical to reveal the effect on these actions during the years of campaign for the region.

2. Material and Methods

In the current study is implemented the Sustainable Development Index in order to reveal the effect on local communities and the region and the Data Envelopment Analysis in order to clarify the effect on the NWSE, mostly if the campaign caused lack of efficiency in it. Sustainable development index approach is quite suitable and allows comparison with next campaigns. The study period in the present study covers the sub periods 2013-2015, which immediately precedes the consolidation and the period 2016-2017, after it.The information needed to calculate the indices and DEA is based on the consolidation data from the enterprise, the annual financial statementsand data from the forestry documentation. In the study are isolated and included in the SDI only those factors that may arise from the consolidation and from the overall activity of the NWSE, influencing the region.

3. Sustainable Development Indicators

According to Harmsen and Powell [5] there exists a many of sustainability indices, indicators, and metrics, as well as tools and methodologies for implementation. Some authors like Dobrota and Iancu [3] explore sustainable development and place theoretical framework that could be used to industrial organizations as well as for agribusiness of forestry. According to Landeta Manzano et al. [9], Lu et al. [10] and Hemdi et al. [6] provide index including stepwise-arranged indicators. Authors like Gospodinova and Krachunov [4], Nedeva [12], propose to be implemented an index for sustainable development with indicators needed to the particular economic system or goal. In the study have been used Sustainable development index approach proposed by Nedeva [12], Gospodinova and Krachunov [4], and implemented by Neykov et al. [11] for the entire Forestry sector in Bulgaria .Methodology is suitable for grouping and assessing sustainability of particular economic system in dynamic aspect with usage of increments (growths) than any static indicators. The index includes sum of weighted indicators:

$$\sum_{1}^{1} q_1 = 1 \quad (1)$$

The index of sustainable development (SDI) is following:

$$SDI = q_1 \cdot l_1 + q_2 \cdot l_2 + q_3 \cdot l_3 \quad (2)$$

where:

q_i are weights of the I_i;

I_i – average of individual increment ratios of Economic, Environmental and Social possible outcomes after the consolidation for the group;

i – number for the indicators group: 1 for Economic, 2 for Environmental and 3 for Social.

The indicators for Economic, Environmental and Social outcomes after the consolidation are following:

A. Economic

- Net annual increment of stock;
- Increment of forests for wood supply;
- Increment of forests for non-wood supply;
- Increment of area of Forest available for wood supply;
- Increment of area of Forest not available for wood supply;
- Increment of welfare in the poorest region;
- Increment of welfare total.

The weights selection is a key process for the index. They can be chosen in various ways, but according to Böhringer [1] shares can be equal, expertly determined or just subjective. In this research, we use three approaches: by share of number of the indicators of each group in all indicators; share of the increments sum of each group into the sum of all increments of all groups.

B. Efficiency Ratios

The Efficiency Ratios of the Northwestern State Enterprise:

- Y_{1j} = Annual Revenues/Fixed assets;
- X_{1j} = Annual Revenues/Subsidiaries for Fixed assets;
- Y_{2j} = Annual Revenues/Land Properties;
- Y_{3j} = Annual Revenues/Investments in Land Properties;
- X_{2j} = Annual Revenues/Expenses for fixed assets.

C. The DEA analysis

The Efficiency ratios are compared year to year in order to determine whether the Enterprise was efficient in the particular year. The methodology of comparison is Data Envelopment Analysis (DEA), which is appropriate to estimate the efficiency in each year by comparing it to the most efficient year within the period.

- Each year is called Decision Making Unit in the model.
- The Enterprise is efficient if in the particular year the Total Efficiency (θ) is equal to 1.

The model:

$$\min \theta \quad (3)$$

Subject to:

$$\sum_{i=1}^{n} \lambda_j x_{ij} - \theta x_0 \leq 0 \quad (4)$$

$$\sum_{i=1}^{n} \lambda_i y_{ij} - y_0 \geq 0 \quad (5)$$

where:

λ_j are individual year weights, calculated by the model;

X_{ij} – inputs - the calculated efficiency ratios for "Subsidiaries for Fixed assets" and "Expenses for fixed assets" under number i for the year j;

Y_i – outputs are calculated efficiency ratios of Fixed assets, Land Properties under number i for the year j.

4. Results

The indicators, included in the index of sustainable development for the period after consolidation, are presented in Table 1.

Table 1

Indicators-increments included in the SD index for 2016-2017

Increments	Economic	Social	Environmental
Net annual stock increment			5.88%
Forests for wood supply	1.55%		
Removals	4.17%		
Forests for non wood supply			11.05%
Area of Forest available for wood supply	3.47%		
Area of Forest not available for wood supply			3.21%
Welfare in the poorest region		0.022%	
Welfare total		0.016%	

The presented results show that the economic factors of development have improved by a total of 9.19%. The economic development of the region depends on yields, and they have increased by 4.47%. In the interest of truth, this increase is not an isolated result of the consolidation, but a joint effect of the overall activity of the enterprise. As mentioned, the purchase of forest properties continued after the campaign and partially led to changes in Table 1. As can be seen in Table 1, the social indicators, namely the money went to local communities, as a result of consolidation are quite small in terms of growth - 0.022%. The index also includes the overall increase in welfare in the country for the studied periods and shows that the region is ahead of overall welfare improvement of the country for the years of consolidationwith 0.08%. The table reveals that the most significant increase is in the group of indicators improving the environment on the territory of the enterprise - 20.14%. The data from the Table 2 show the impact of consolidation on the selected indicators. It was mostly on environmental manner. But whether the consolidation improved something is revealed by the SDI, calculated with data before the consolidation (Table 2).

Table 2

SDI with different preferences and comparison to SDI before consolidation

Preferences	Index [%]	Weights [%]		
		Economic	Social	Environmental
By number	9.79	37.50	25.00	37.50
By share	13.11	38.22	0.16	61.62
On unversal purpose	8.62	33.00	33.00	33.00
Comparison				
By share 2016-2017	13.11	12.65	0.04	13.43
By share 2013-2015	1.97	12.18	0.00	-4.36

The results in Table 2 show that the index increases with increasing weights of economic and environmental effects, but not of social ones. Changing the weights is a process of setting preferences on some group of increments. Social impact improved only by 0.04% after the consolidation period. The social effects must have a very significant increase, at least as much as the economic factors or approximately 9% to become a real output of the consolidation. This is a proof that whatever the preferences are set in the calculation of the index, it does not lead to an indication of social development. The obvious result is that the SDI after 2016 is higher, than of previous period. Here are involved influences of many other factors that are not possible to be excluded according to available data, but it is fact that the NWSE faced changes just after the consolidation and especially in improvement of territories not economically valuable. It is interesting that the influence of economic factors – increments remain almost unchanged, which proves the sustainability of economic activity.

Analyzing the forest enterprise in the most backward region of Bulgaria, it can be seen that some inefficiencies have occurred. Figure 1 shows the economic ratios for the study period in the enterprise.

The ratios reveal the diminishing efficiency ratios of some of the assets. Financing for fixed assets reveal the state influence, it fell in about 14 EUR. The enterprise has been created to function independently by the state. The independence was partially reduced during the campaign and afterward the ratio for financing-subsidiaries remained stable in amount of 4 EUR. Expenses for purchasing fixed assets are getting more efficient for the whole period. The enterprise began investing in forests not in any other land or kind of properties that are not connected to the forest activities just after the consolidation campaign. The curve changed direction and achieved in the end of the 2018 60 EUR. This is a result of the low costs made by the Enterprise for documentation preparation, external services and taxes. All the outcomes described above are contradictory and here comes DEA. It is not clear whether

NWSE became more or less efficient after the consolidation. The results are presented in Figure 2.

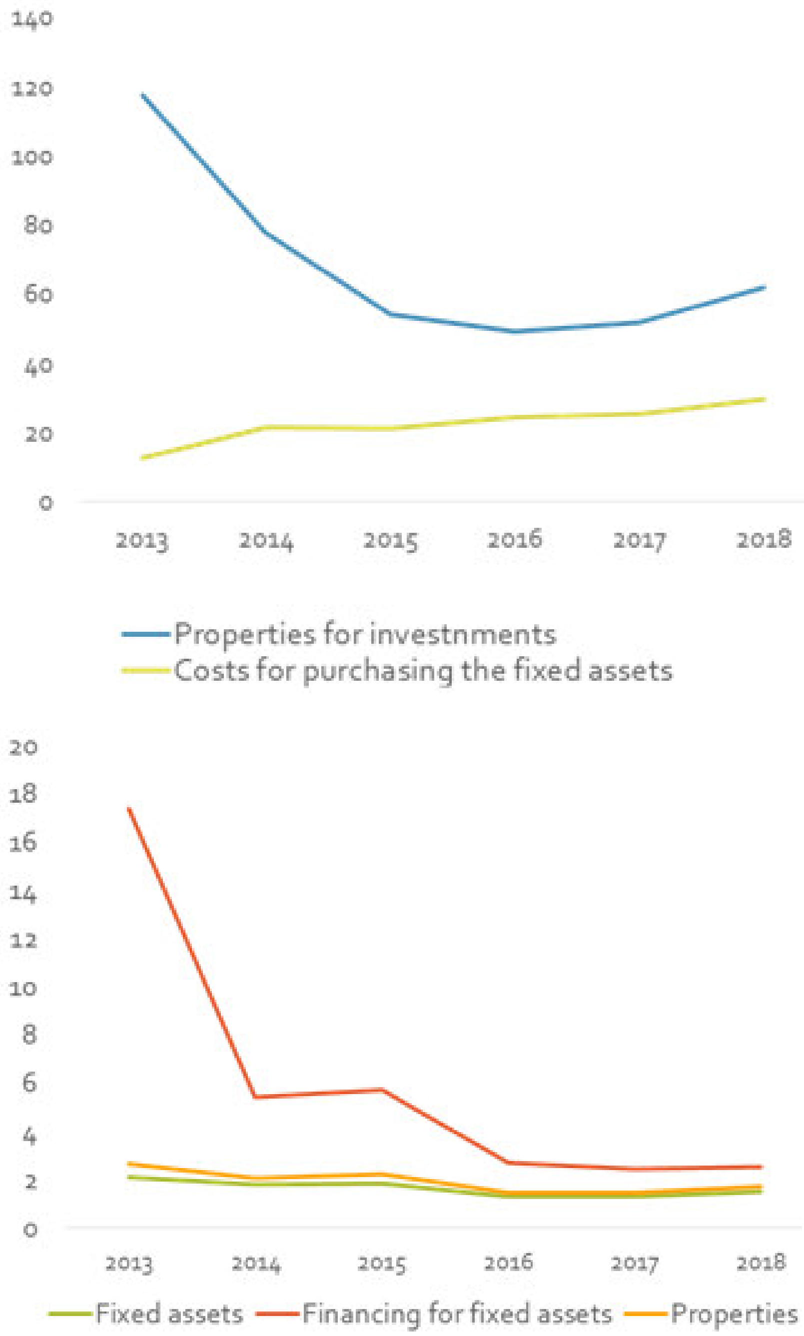


Fig. 1. *The economic ratios included in Data Envelopment Model for the Northwestern State Enterprise in Bulgaria*

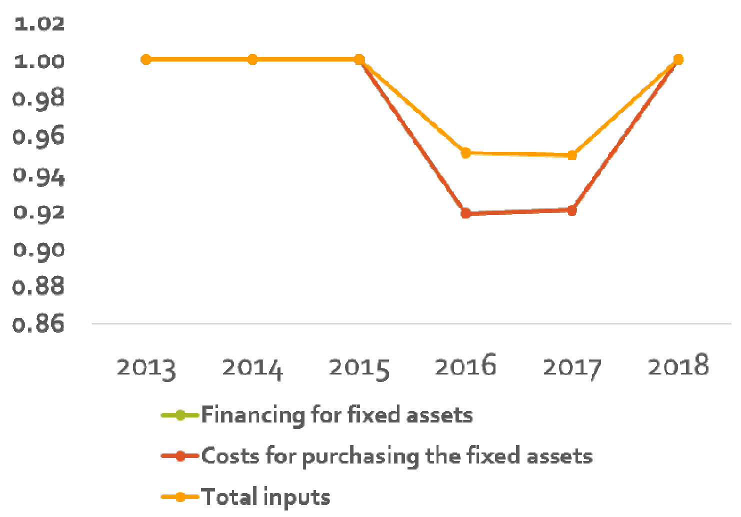


Fig. 2. *DEA efficiency scores "ϑ" for Northwestern State Enterprise, using particular input ant total inputs*

DEA reveals the lack of efficiency during the campaign. All the years before and after it are efficient - θ=1. Here the results are clearer, than in the ratios. This proves the role of DEA in this analysis. The model also calculates the problematic outputs (ratios as "Efficiency of Properties" and "Efficiency of properties for investments"). The figure shows the positive combine effect of the inputs. The consolidation cannot be undergone without state financing and efficient procedures.

5. Discussion

Results proved that in fact the main purpose of the consolidation was bettering the steering of the territories, than improving the efficiency. The actions taken by the government through funding and instructions for consolidation have had a rather one-sided effect. Of interest is the remaining the environmental condition of the enterprise. The economic improvement was not in the focus. The campaign was accomplished with slightly influence on the enterprise efficiency, but DEA revealed, that campaign in fact influenced the enterprise. Some of preliminary set goals to improve the efficiency of forest activities were partially met. But in the same time throughout the nature of SDI is revealed the most problematic area, i.e. social. The payments were too insufficient to place an effect on the local communities. That was the reason to be included the economic state of the poorest region not only in Bulgaria, but in EU. If something was about to happen in result of consolidation, there was the most appropriate place this effect to be most obvious. But this did not happen. Again the SDI proved it is applicability in consolidation outputs assessment.

When move to the micro level results proved the assessment SDI. The lower efficiency caused the lower payment for forestry workers and struggles to the management, it is slight, but obvious.

Despite the increase of external financing the efficiency of the Enterprise fell down, because the higher value of some of the parcels. In the same time the Enterprise reaches efficient levels after two years. This can be a result of the remaining economic growth (as can be seen from Table 2) of the enterprise after the consolidation process. The enterprise remained stable, but in a different state. The subsidies became the great part of inbound financial flows and consequently the influence of the state.

6. Conclusions

It may be assumed that the consolidation in the way it is carried out in Bulgaria resulted in quantitative changes and dynamic stabilization. The consolidation process resulted mainly in environmental and slightly social benefits it. It partly gained effect over preliminary placed targets. Implementation of the SDI provides quantitative approach for assessment of consolidation campaigns in the level of the entire country. DEA assessment revealed that subsidiaries were insufficient for the investigated Northwestern State Enterprise. Subsidiaries caused too small effect both on the local communities and the state enterprises. The steering of the territories have been improved since there are significant changes on environmental increments of SDI. The consolidation is quite suitable to enterprises like NWSE where the protected territories are 26%. Enlarging the territories purchased through consolidation campaign in NWSE provided an opportunity to foster the capabilities of forest management interventions through transferring areas from private owners to state steered ones.

In the current study have been made following recommendations:

- In the case of campaigns to be grant larger subsidiaries. For the national level according to the SDI the subsidiaries could be raised in about 7%, and in the level of particular enterprise: 1% - 10%;
- When consolidation campaign is to be carried out the purposes placed in the preliminary discussions to be assessed by the SDI index;
- DEA to be used for the enterprise level of planning for consolidation activities whenever they are undertaken.

Acknowledgements

This work was kindly supported by the project НИС-Б-1074/16.03.2020 – “Creating a model for supporting the consolidation of landed properties in forest areas in the Republic of Bulgaria”, implemented at the University of Forestry, Sofia, Bulgaria.

References

1. Böhringer C., Jochem P., 2006. Measuring the immeasurable – A survey of sustainability indices. In: Ecological Economics, vol. 63(1), pp. 1-8. ZEW. Zentrum für Europäische Wirtschaftsforschung. Discussion Papers, no. 06-073, Mannheim, 14p.
2. Demetriou D., 2014. Land consolidation. In: The Development of an Integrated Planning and Decision Support System (IPDSS) for land consolidation. Springer Theses (Recognizing Outstanding Ph.D.

Research). Springer, Cham. https://doi.org/10.1007/978-3-319-02347-2_3.

3. Dobrota D., Iancu C., 2015. Sustainable development of an industrial organization. In: Annals of the "Constantin Brancusi" University of Targu Jiu, Engineering Series, No. 2, pp. 164-173.
4. Gospodinova N., Krachunov H., 2010. Principles and indicators for sustainable development assessment of rural areas in Bulgaria. In: Management and Sustainable Development, vol. 34(27), pp. 184-188.
5. Harmsen J., Powell J.B. (Eds.), 2010. Sustainable development in the process industries: Cases and Impact. John Wiley & Sons. DOI: 10.1002/9780470586099.
6. Hemdi A., Mat Saman M.Z., Sharif S., 2012. Fuzzy application in sustainability assessment: A case study of automotive headlamp. In book: Sustainable Manufacturing, G. Seliger (Ed.), SpringerVerlag Berlin Heidelberg, pp. 49-56. DOI: 10.1007/9783642272905_8.
7. Kies U., Peter A., 2017. Forest land consolidation of community forests in North Rhine-Westphalia. Readjustment of property as a solution for land fragmentation and inactive small-scale private forest owners in Germany. SIMWOOD Pilot Project NRW Summary Report,p. 3.
8. Kolis K., Hiironen J., Riekkinen K. et al., 2017. Forest land consolidation and its effect on climate. In: Land Use Policy, vol. (61), pp. 536-542.
9. Landeta Manzano B., Arana-Landin G., Ruiz de Arbulo P. et al. 2015. Sustainability through Eco-Design: Shedding light on the adoption of the ISO 14006 Standard. In book: Sustainable Operations Management, Measuring Operations Performance, pp. 163-181. DOI: 10.1007/9783319140025_8.
10. Lu T., Rotella G., Feng S.C. et al., 2012. Metrics based sustainability assessment of a drilling process. In book: Sustainable Manufacturing, G. Seliger (Ed.), Springer Verlag Berlin Heidelberg, pp. 49-56. DOI: 10.1007/9783642272905_8.
11. Neykov N., Antov P., Savov V., 2018. Sustainable development and forest-based industries: Main considerations and policy measures. In: The Bulgarian Example, Open Economics, vol. 1, pp. 86-93.
12. Nedeva I., 2010. Methodology for assessing the sustainable development of industrial zones. In: Scientific Work of the University of Ruse, vol. 49(1.2), pp. 98-102.
13. Vitikainen A., 2004. An overview of land consolidation in Europe. In: Nordic Journal of Surveying and Real Estate Research, vol. 1(1), pp. 23-44.
14. https://www.dictionary.com/browse/decare. Accessed on: 25 May, 2021.
15. https://www.lex.bg/laws/ldoc/2135721295. Accessed on: 25 May, 2021.

NATURE-BASED RECREATION IN PERI-URBAN AND SEMI-NATURAL FORESTS: THE VISITORS' PERSPECTIVE IN TWO CASE STUDIES IN ITALY

Alessandro PALETTO[1] Isabella DE MEO[2]

Abstract: *The nature-based recreation is one of the most important ecosystem services offered by forests, providing benefits to local economy, human health and well-being, reducing depression and mental illnesses risk and increasing social interactions. The aim of the present study is to assess the importance of man-made and natural features to influence the attractiveness of two forest destinations in Central Italy: a peri-urban forest closed to a metropolitan area (Monte Morello forest) and a semi-natural forest over 50 km away from an urban area (Pratomagno forest).To assess visitors' preferences towards man-made and natural features, the study was organized in three steps: development and pre-testing of a semi-structured questionnaire; identification and administration of the questionnaire to the sample of visitors (approximately 200 in each study area); data processing and comparison between the two study areas. The stand features investigated in the on-site survey were: tree species composition and stand structure, visual-aesthetic characteristics of forest after different silvicultural treatments, and presence of recreational facilities. The results show that the forest destination with the highest attractiveness is an uneven-aged mixed forests regularly managed with silvicultural treatments. Conversely, pure conifer or broadleaved forests have a low destination attractiveness as-well-as even-aged forests characterized by a low height and diameter differentiation of trees. In accordance with visitors' opinions the recreational facilities have a high importance to increase the destination attractiveness of the peri-urban forests, while in natural forests these man-made features are not perceived as important by visitors.*

Key words: *forest recreation; visitors' preferences and perception; silvicultural treatments; questionnaire survey; Tuscany region (Italy).*

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA), Research Centre Forestry and Wood, p.za Nicolini 6, 38123 Trento (Italy);
[2] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA), Research Centre for Agriculture and Environment, via Lanciola 12/A, 50125 Firenze (Italy);
Correspondence: Alessandro Paletto; email: alessandro.paletto@crea.gov.it.

1. Introduction

In the last decades, the nature-based recreation has taken on growing importance from the socio-economic point of view due to its capacity to facilitate social interactions, to create green jobs opportunities, to improve the local economy, and to promote social cohesion [6, 11]. Nature-based recreation is defined as outdoor activities in natural settings or otherwise involving in some direct way elements of nature such as soil, vegetation, wildlife, water bodies [5]. In nature-based recreation, forest ecosystems play a key role providing attractive sceneries for several outdoor activities such as hiking, mountain biking, fishing, hunting, bird watching, picnicking, non-wood forest products collecting [13]. As emphasized by some authors, the attractive sceneries for outdoor activities provided by forests can be quantified in terms of destination attractiveness [8, 16].

The attractiveness of a destination is the perceived ability of the destination to deliver individual benefits [22] and it is influenced by two main features of the destination [19, 33]: innate or natural features (e.g., natural resources, climate, ecology, hydrology etc.) and man-made features (e.g. accommodations, facilities for sport and recreational activities etc.). With special regard to forest destination, forest management practices can influence the destination attractiveness by intervening on stand characteristics such as [17, 29]: forest system (coppice vs. high forest), horizontal and vertical stand structure (even-aged vs. uneven-aged stand), tree distribution in the space (random, regular and cluster tree distribution), tree species composition (pure vs. mixed forest stand), and stand density (open vs. closed forest). Forest managers can influence also the man-made features improving path and road network, creating recreational facilities (picnic areas, bird watching stations) and sports, educational, or historical-cultural paths [20].

In the international literature, the attractiveness of a destination can be assessed by four main approaches [30]: geographical approach, economic approach, presentation approach, and perceptive approach. In the geographical approach, the attractiveness of the destination is determined by the number, importance, and spatial placement of individual elements such as landscape aesthetics, climate, water bodies, flora, fauna, and cultural heritage. The destination attractiveness in the economic approach is estimated considering as explanatory variables the number of visitors and the number of arrivals, length of stay (in days and hours), costs incurred by visitors, employments in tourism sector. In the presentation approach, the attractiveness is strictly related to marketing communication strategies and the way a site is presented to the potential visitors. In the perceptive approach, the attractiveness of a destination is related to the individuals' perception of the destination capability to meet their needs.

In this latter approach, the visitors' opinions, preferences, and perceptions are the starting point for the definition of management strategies aimed at improving the destination attractiveness [9]. Other authors classified the approaches for improving the destination attractiveness in two groups [1, 2]: supply and demand approaches. The supply approach focuses on the physical (man-made and natural) features of the destination [21], while the demand approach considers the psychology of visitors and the perceived ability of destinations to satisfy their individual needs [10]. In this way, forest management practices have a direct influence on physical features, while the marketing communication and awareness strategies can generate a psychological effect on visitors increasing the site attractiveness [28].

Starting from these considerations, the aim of the present study is to assess the importance of man-made and natural features to influence the attractiveness of two different forest destinations in Central Italy. The attractiveness of the two selected destinations – a peri-urban forest closed to a metropolitan area and a semi-natural forest over 50 km away from an urban area – was assessed using the perceptive approach. The study was conducted within the framework of the LIFE SelPiBio project aimed to develop innovative silvicultural interventions in black pine forests for increasing the provision of ecosystem services, and of the LIFE FoResMit project aimed to improve the multifunctional role of the peri-urban forests with special regard to climate change mitigation. The innovative aspect of this study is to compare the visitors' preferences towards a peri-urban forest and a semi-natural forest in terms of destination attractiveness. The research hypothesis is that visitors have a different perception towards the forests in proximity of urban areas compared to those far from urban areas.

2. Material andMethods

2.1. Study Areas

The research was developed in two study areas located in Tuscany region, in Central Italy. The two areas have been selected considering the proximity of the forest resource to the urban areas. The first study area was identified less than 15 km from a metropolitan area (Florence city, 382.258 inhabitants in the 2017 census), while the second one was identified at more than 50 km from an urban area (Arezzo city, 99.469 inhabitants in the 2017 census). According to the definition provided by Blazevska et al. [4], peri-urban forests are characterized by a low distance from urban areas and a high recreational attendance (e.g. jogging, hiking, dog walking, relaxing, picnicking). Therefore, the first study area selected in this research can be considered a peri-urban forest, while the second one cannot be considered as such.

The first study area is the Monte Morello peri-urban forest (43°51' N; 11°14' E), located close to the urban area of Florence city. The Monte Morello peri-urban forest is a reforestation realized from the first of 1909 until 1980 for protection purpose, on a total area of 1,035 ha [7]. The main tree species used in the reforestation activities are black pine (*Pinus nigra* J.F. Arnold), Calabrian pine (*Pinus brutia* Ten. subsp. *brutia*), cypress (*Cupressus* spp.), flowering ash (*Fraxinus ornus* L.), Turkey oak (*Quercus cerris* L.) and Downey oak (*Quercus pubescens* L.). The altitude of the area is between 55 m and 934 m above sea level (a.s.l.), while the climate is characterized by precipitations concentrated in the period from autumn to early spring and a dry summer in which July is the driest month, while October and November are the rainiest ones. During the last decades (from the early 80s) the total annual rainfall is 1,003 mm and the average annual temperature is 13.9°C. The Monte Morello peri-urban is an important recreational destination with 18,475 visitors per year mainly coming from the province of Florence [25].

The second study area is the Pratomagno forest (43°39′ N 11°39′ E) located in the North-West of the Arezzo province. The Pratomagno was affected by reforestation activities started in 1954 and ended in the 1980s with the aim to increase water and soil erosion protection, and to avoid landslides and other natural hazards. The main tree species used in the reforestation activities were Calabrian pine (*Pinus brutia* Ten. subsp. *brutia*), Austrian black pine (*Pinus nigra* J.F. Arnold), and some broadleaved species such as Turkey oak (*Quercus cerris* L.), European beech (*Fagus sylvatica* L.), Downey oak (*Quercus pubescens* L.) and flowering ash (*Fraxinus ornus* L.). The climate is characterized by an average annual temperature of 10.5°C (maximum 19°C in July and minimum of 1.5°C in January), while the average rainfall is 997 mm with a maximum peak in autumn and a minimum precipitation in June. From the recreational point of view, the Pratomagno forest is a quite important recreational destination with an average number of visitors per year of 5,140 [24].

2.2. Research Structure

The study was organized as an on-site survey and was structured in three steps: (1) development and pre-testing of a semi-structured questionnaire; (2) identification and administration of the questionnaire to the sample of visitors; (3) data processing and comparison of the results between the two study areas. The aim of the questionnaire was to assess the influence of stand features on destination attractiveness.

In the first step, a preliminary version of the questionnaire was developed by researchers and local experts involved in the projects' activities. The preliminary version of the questionnaire was pre-tested with five visitors of the Pratomagno forest and four visitors of the Monte Morello peri-urban forest. The pre-test stage was performed with the aim of identifying critical questions and to estimate time for completing the questionnaire. After the pre-test stage, two questions have been simplified and one question has been deleted in accordance with visitors' comments and suggestions.

The final version of the questionnaire was formed by closed-ended and open-ended questions divided in three thematic sections. The first section focused on the recreational attendance of the destination such as: number of visits to the forest site in the last 12 months; preferred visiting days (weekend or both weekend and working days); number of persons and time of current visit (all day, a few hours, less than an hour); vehicle used and kilometers traveled in current visit; costs incurred for the visit (meals, accommodation, other expenses); visiting group (alone, with family members, with friends, in organized group); and reasons for visiting.

In the second section, the respondents assigned their preferences for the natural features of the stand such as tree species composition (distinguishing between mixed forests, pure broadleaved forests and pure conifer forests)and stand structure (distinguishing between uneven-aged forests with random distribution of the trees in the space and even-aged forests with regular distribution of the trees in the space). For these two natural features, the respondents gave a single preference. In addition, respondents were asked to assign preferences for the presence of the following man-made features: picnicking areas, sports paths, benches, trail marking, waste baskets. For these man-made features, a multiple preference answer was present in the questionnaire. In the last question of this section, the respondents assigned their visual-aesthetic preferences for some photos representing the forest landscape of Monte Morello and Pratomagno after different silvicultural treatments (selective thinning and thinning from below). In the international literature, there are two main approaches to evaluate the sense of landscape: on-site approaches and off-site approaches. In the on-site approaches the sense of landscape is evoked by a real experience in the forest, while in the off-site approaches the sense of landscape is evoked by a representative sample scene [12]. Regarding the off-site approaches, the most common methods are photo elicitation (presentation of the landscape in a two-dimensional photo) and virtual reality (presentation of the landscape in a virtual three-dimensional scene) [3]. Sevenant and Antrop [31] highlighted that the photo elicitation method cannot provide complete visual information compared to the real situation. To overcome these limitations, in the present study a mixed on-site and off-site approach was used: the visitors were interviewed in the forest site, but the three forest management situations were shown using the photo elicitation method.

The three forest management situations investigated in this study can be described as follows:

1. Without silvicultural treatments: current situation in both study areas characterized by no silvicultural interventions, the standing dead trees and the lying deadwood are not removed;
2. Selective thinning: in this situation the choice of the trees to be cut is based on a positive selection (thinned 30-40% of basal area). During cutting all crown-volume competitors trees are harvested, standing dead trees and lying deadwood of first decay classes are removed;
3. Thinning from below: in this situation the choice of trees is based on a negative selection (thinned from below 15-20% of basal area). During cutting only small and leaned trees and standing dead trees are harvested, while the lying deadwood is not removed during the silvicultural treatments.

During the interview, the visitors compared the three photos in pairs (pair wise comparison), according to the following scheme:

Photo A	5	3	1	1/3	1/5	Photo B

The preferred image by the visitors was identified with the calculation of the priority value of each image followed the method proposed by Paletto et al. [25].

The third section of questionnaire considers socio-demographic characteristics of respondents such as: gender; age (distinguishing among four classes: less than 25 years old; 25-44 years old, 45-64 years old and more than 64 years old); level of education (elementary school degree; high school degree; university and post-university degree); occupation (employed in the public and private sector; housewife; student; pensioner; unemployed); and place of origin (distinguishing between administrative province where the study area is located; other provinces of Tuscany region; other Italian regions, and foreign countries).

In the second step, the visitors have been systematically selected in two sampling points in each study area. The criteria used to select the sampling points were the accessibility and the presence of landscape observation points. The visitors to be interviewed were selected one for every two that arrived in the two sampling points. In both study areas, the questionnaire was administered face-to-face to a sample of visitors in the spring-summer period. The questionnaire was administered to the visitors by a lead interviewer and an assistant, both in working days and weekend to include in the sample different types of visitors (single visitor, couples, families, groups of friends).

In the last step, the data were processed to produce the main descriptive statistics: mean, median and standard deviation for the data collected using the Likert-scale format, percentage of frequency distribution (%) for other questions. The results were presented by case study and considering two of the socio-demographic characteristics of respondents: gender and age. Finally, the data of the two study areas were statistically compared using the Chi-square (χ^2) test (α=0.05).

3. Results

3.1. Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of respondents of the two study areas are shown in Table 1.

In the Monte Morello area, the response rate was 75.0%: 201 visitors completed the questionnaire, while 68 refused to fill out the questionnaire. The sample of respondents is composed of 59.7% males and 40.3% females, while the age distribution of the respondents shows that around72 % is between 25 and 64 years old. Regarding the level of education, the distribution of the sample of respondents' evidences that most of respondents (around 70%) has a high school or University degree. Concerning the occupation, the sample of respondents is mainly composed by people employed in private or public sector (47.3% of total respondents), followed by retirees (26.4%), unemployed people (6.5%), students (6.0%), and housewives (4.5%). The remaining 9.3% is distributed in other jobs not mentioned in the proposed list.

The target of visitors of Monte Morello forest is mainly represented by local visitors, in fact 68.0% comes from Florence province and 26.0% from other provinces of Tuscany Region.

In the Pratomagno area, the response rate was 22.2% (200 questionnaires collected and processed), while the non-response rate ranges between a maximum of 85.0% on holidays and Sunday and a minimum of 70.0% on Saturday and working days. Most respondents in our sample are males (62.0%), while the remaining 38.0% are females.

Table 1

Socio-demographic characteristics of respondents in the two study areas

Socio-demographic characteristics/Study area	Monte Morello (*n*=201)	Pratomagno (*n*=200)
Gender		
Male	59.7%	62.0%
Female	40.3%	38.0%
Age		
Less than 25 years old	4.5%	20.9%
25-44 years old	30.3%	33.2%
45-64 years old	41.8%	32.8%
More than 64 years old	23.4%	13.1%
Level of education		
Elementary and technical school degree	26.9%	19.1%
High school degree	40.8%	44.2%
University and post-university degree	32.4%	36.7%
Occupation		
Employed	47.3%	52.0%
Housewife	4.5%	4.5%
Students	6.0%	19.0%
Retirees	26.4%	14.0%
Unemployed	6.5%	10.5%
Other	9.3%	0.0%
Place of residence		
Administrative province of the study area	68.0%	88.5%
Other provinces of the Tuscany regions	26.0%	10.5%
Other Italian regions	4.0%	1.0%
Foreign	1.0%	0.0%

Also in Pratomagno the distribution of respondents by age shows that most respondents (66%) are between 25 and 64 years old. Regarding the level of education, the results show that most respondents have a high school degree or University degree (around 80% of total respondents). The distribution of respondents by occupation show that 52.0% of respondents is employed in public or private sector, 4.5% are housewife, 19.0% are students, 14.0% are retirees, while the remaining 10.5% are unemployed people.

Finally, the visitors of Pratomagno forest mainly come from the same province (Arezzo province) where the forest is located (88.5%), while 10.5% of visitors come from the Firenze province and no visitor comes from foreign countries. These results demonstrate that most visitors are local persons (hikers, pickers), while the number of tourists is quite low.

3.2. Preferences for the Natural Features

The results show that the visitors of Monte Morello area prefer mixed forests

(69.7% of total respondents), followed by broadleaved forests (20.9%) and conifer forests (9.5%). Likewise, most of the visitors of Pratomagno area prefer mixed forests (67.8%), while pure broadleaved forests (16.6%) and pure conifer forests (15.6%) are less appreciated. The Chi-square (χ^2) test (α=0.05) shows no statistically significant differences between the two study areas (p=0.133).

Observing the data by socio-demographic characteristics, the results show in Monte Morello area a higher preference of females for mixed forests compared to males (77.8% vs. 64.2%); conversely, males have a higher preference respect to females for pure broadleaved forests (22.5% vs. 18.5%) and pure conifer forests (13.3% vs. 3.7%). Similarly, in Pratomagno area females show a higher preference for mixed forests (70.7% vs. 65.9%) and for pure broadleaved forests (18.3% vs. 16.3%) compared males, while males prefer pure conifer forests compared females (17.9% vs. 12.0%). In Monte Morello area, the results by age show that the preference for pure conifer forests increases in the older age classes (0% of the respondents with less than 25 years, 4.9% between 26 and 44 years, 9.5% between 45 and 64 years, 17.0% with more than 64 years). Conversely, this trend is not observed for the responses of visitors to Pratomagno area.

Regarding the stand structure, the results show that the visitors of Monte Morello prefer uneven-aged forests (88.7% of total respondents) as-well-as the visitors of Pratomagno (77.3%). The Chi-square (χ^2) test (α=0.05) shows a statistically significant differences between the two study areas (p=0.017). Observing the data by gender, in Pratomagno females express a clearer preference for uneven-aged forests compared to males (80.3% vs. 75.0%), while in Monte Morello no differences are found between females and males. Analyzing the data by age, a relationship between age and preferred structure is highlighted for the visitors of Monte Morello. In fact, uneven-aged forests are preferred by 75.0% of visitors with less than 25 years old; 82.4% of visitors aged 25-44 years; 90.6% of visitors aged 45-64; and 96.6% with more than 64 years. Therefore, it can be said that uneven-aged forests are more appreciated by older people, while even-aged forests by younger ones.

The results concerning the impacts of silvicultural treatments on visual-aesthetic preferences (Table 2) show that for the visitors of Monte Morello peri-urban forest the preferred situation is Photo 3 (priority score of 0.5034), followed by Photo 2 (0.2873) and Photo 1 (0.2093). Similarly, the visitors of Pratomagno forest assigned the same order of priority but with closer scores: Photo 3 (priority score of 0.4014), followed by Photo 2 (0.3358) and Photo 1 (0.2628).These results show that in both study area visitors prefer managed forests (Photo 2 and 3), while unmanaged are evaluated negatively from the visual-aesthetic point of view by the respondents.

Regarding the gender, for both study areas females assign higher value to managed forests (Photo 1 and 2) compared to males; conversely, males assign higher value to unmanaged forests (Photo 3) compared to females.

Regarding the age, in Monte Morello the results show a trend of decrease of the Photo 1 priority score (unmanaged forests) when the age of respondents increases, while the priority score of the Photo 2 and 3 (managed forests) increases when the age of respondents increases (Figure 1). In Pratomagno there is no trend in the association between photos preferences and age of respondents.

Table 2

Priority scores assigned by the visitors to three forest management situations shown using photos

Photo/Study area	Monte Morello (*n*=201)	Pratomagno (*n*=200)
Photo 1 - Without silvicultural treatments	0.2093	0.2628
Photo 2 - Thinning from below	0.2873	0.3358
Photo 3 - Selective thinning	0.5034	0.4014

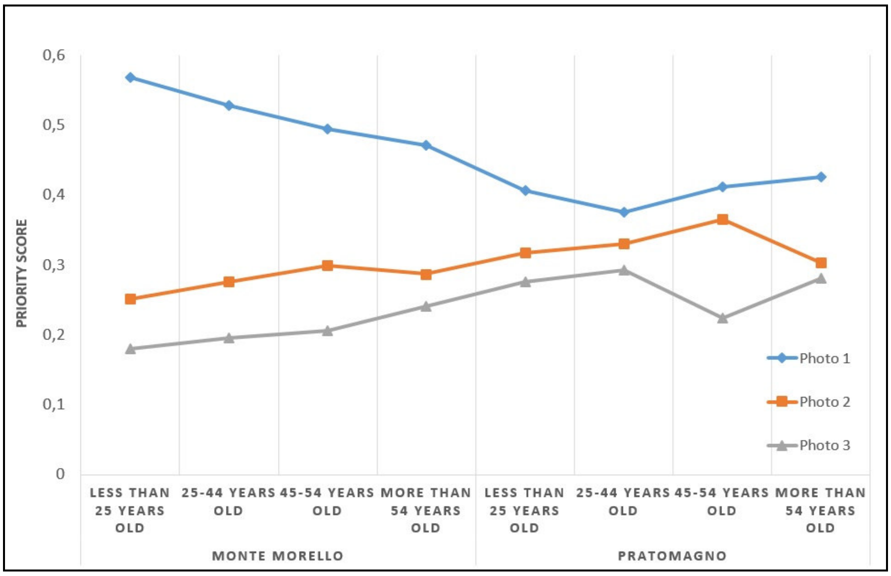


Fig. 1. *Priority scores for the three forest management situations in the two study areas by age*

Summarizing the results, the forest destination with the highest attractiveness is an uneven-aged mixed forest regularly managed. Conversely, pure conifer or broadleaved forests have a low destination attractiveness as-well-as even-aged forests characterized by a low height and diameter differentiation of trees. Finally, also the unmanaged degraded forests are perceived negatively by the visitors.

3.3. Preferences for the Man-Made Features

The results show that for the visitors of Monte Morello peri-urban forest all man-made features have a high importance to increase the destination attractiveness. Figure 2 shows that waste baskets (58.2% of total respondents) and picnicking areas (54.7%) are considered the two most important recreational facilities, while trail marking is considered the least important (44.8%). Conversely, for the visitors of Pratomagno forest only trail marking is considered quite important (54.5%), while the other four recreational facilities are considered important by less than 40% of total respondents. The Chi-square (χ^2) test (α=0.05) shows statistically significant differences between the two study areas (p=0.017).These differences show that visitors perceive recreational facilities more positively in urban and peri-urban forests, while in natural forests most visitors perceive in a positive way only the trail marking (Figure 2).

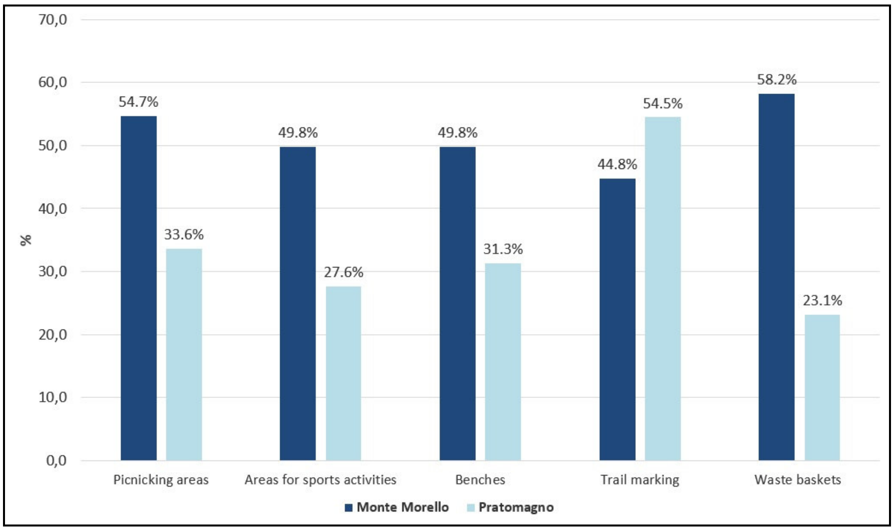


Fig. 2. *Visitors' preferences for man-made features in the two study areas*

Observing the data by gender (Table 3), in the Pratomagno the results show that males considered more important than females the presence of area for sports activities (23.4% vs. 11.8%), while females consider the other four recreational facilities more important than males: picnicking areas (23.7% vs. 22.6%), benches (25.0% vs. 18.5%), trail marking (38.2% vs. 35.5%), waste baskets (19.7% vs. 12.9%).Similarly, in Monte Morello, males assigned a higher preference than females to picnicking area (58.3% vs. 49.4%), sports areas (53.3% vs. 44.4%), while females assigned a higher preference to benches (50.6% vs. 49.2%), trail marking (45.7% vs. 44.2%), and waste baskets (60.5% vs. 56.7%).

The results by age show that in both study areas young visitors (less than 25 years old) assigned a lower level of importance to all recreational facilities compared to other visitors. Distinguishing between visitors with less than 25 years old and all other age classes, the results are distributed as follows,: picnicking areas (Monte Morello 33.3% vs. 55.7%; Pratomagno 19.0% vs. 24.1%), areas for sports activities (Monte Morello 44.4% vs. 50.0%; Pratomagno 26.2% vs. 17.1%), benches (Monte Morello 22.2% vs. 51.0%; Pratomagno 14.3% vs. 22.8%), trail marking (Monte Morello 44.4% vs. 44.8%; Pratomagno 28.6% vs. 38.6%), waste baskets (Monte Morello 55.6% vs. 58.3%; Pratomagno 7.1% vs. 17.7%).

Table 3

Visitors' preferences for man-made features in the two study areas by gender and age

Socio-demographic characteristics/Facilities	Picnicking areas	Sports areas	Benches	Trail marking	Waste baskets
Monte Morello (*n*=201)					
Gender					
Male	58.3%	53.3%	49.2%	44.2%	56.7%
Female	49.4%	44.4%	50.6%	45.7%	60.5%
Age					
Less than 25 years old	33.3%	44.4%	22.2%	44.4%	55.6%
25-44 years old	59.0%	55.7%	49.2%	47.5%	55.7%
45-64 years old	57.1%	48.8%	54.8%	42.9%	61.9%
More than 64years old	48.9%	44.7%	46.8%	44.7%	55.3%
Pratomagno (*n*=200)					
Gender					
Male	22.6%	23.4%	18.5%	35.5%	12.9%
Female	23.7%	11.8%	25.0%	38.2%	19.7%
Age					
Less than 25 years old	19.0%	26.2%	14.3%	28.6%	7.1%
25-44 years old	24.2%	18.2%	15.2%	36.4%	16.7%
45-64 years old	25.8%	21.2%	27.3%	45.5%	19.7%
More than 64 years old	19.2%	3.8%	30.8%	26.9%	15.4%

4. Discussion and Conclusions

The results provided by the present study show that the destination attractiveness of a forest is deeply influenced both by the natural features of the stand and by man-made features. However, visitors' requests and expectations are strictly related to the forest destination with special regard to the proximity to the urban areas and to the intensity of recreational use. Visitors' requests for urban and peri-urban forests – close to urban areas and intensively used for recreational activities – are a natural environment, but with all possible "comforts" such as easy trail marking, equipped picnic areas, other recreational facilities. The preferences of Monte Morello visitors confirm that all recreational facilities (picnicking and sports areas, benches, trail marking, waste baskets) are appreciated to improve the usability of the site. Conversely, in semi-natural forests away from urban areas – such as Pratomagno forest –recreational facilities are not appreciated by visitors who are looking for greater landscape naturalness. Regarding the innate features, in both study areas the preferred situation is an uneven-aged mixed forest regularly managed. Instead, the planted pure forests – such as the two study areas of the present research – were characterized by medium-low recreational attractiveness.

In the international literature, some studies have shown the visitors' preferences towards mixed forests compared to pure broadleaved and conifer forests [14, 15, 27]. These studies confirmed that the tree species composition is a very important feature to increase the destination attractiveness. In particular, Grilli et al. [14] shown that the mixed forests are preferred by visitors of the Polish Carpathians, while Paletto et al. [23] highlighted that the citizens of Trento municipality prefer mixed forests (66% of 314 respondents), followed by conifer forests (28%) and broadleaved forests (6%). Besides, those authors pointed out that some recreational facilities – e.g., unspoiled nature, paths, parking areas, food vendors – are appreciated by visitors. Similarly, Jankovska et al. [18] highlighted that the visitors of the Riga peri-urban forest perceived the presence of tourist facilities – e.g., waste baskets, picnicking and sport areas – in a positive way. Pastorella et al. [26] show that visitors of a high mountain forests in Italian Alps have a strong preference for mixed forests with a structure characterized by trees with different size (horizontal stand structure) and randomly distributed in the space. Tyrväinen et al. [32] highlighted that the visitors of the urban forest of Helsinki city (Finland) assigned a preference to mixed Scots pine and Norway spruce stands, but conversely mixed stands of deciduous trees are disliked. Besides, those authors emphasized that in accordance with the visitors' opinions the three most important forest management interventions to increase the value of forest landscape are: thinning, management of understory and bush layer, and removal of dead snags.

The results of present study confirmed that in urban and peri-urban forests, like Monte Morello of the present research, a thinning of medium-high intensity has a positive effect from both a visual-aesthetic point of view and accessibility to the forest destination. In addition, in these forests under story and bush layer as-well-as lying deadwood and dead snags must be removed during silvicultural interventions in order to increase the safety and accessibility of the destination. The information provided by this study can be considered a starting point to support forest managers to increase the attractiveness of forest destinations. The future steps of the project will be to investigate further man-made and innate features of different forest stands.

Acknowledgments

This study was carried out and funded by the SelPiBio LIFE project (Innovative silvicultural treatments to enhance soil biodiversity in artificial black pine stands) and the LIFE FoResMit project (Recovery of degraded coniferous Forests for environmental sustainability Restoration and climate change Mitigation).

References

1. An L.T., Markowski J., Bartos M. et al., 2019. An evaluation of destination attractiveness for nature-based tourism: Recommendations for the management of national parks in Vietnam. In: Nature Conservation, vol. 32(6), pp. 51-80.
2. Backman S.J., Uysal M., Backman K., 1991. Regional analysis of tourism resources. In: Annals of Tourism Research, vol. 8(2), pp. 323-327.
3. Bishop I.D., Rohrmann B., 2003. Subjective responses to simulated and real environments: A

comparison. In: Landscape and Urban Planning, vol. 65(4), pp. 261-277.

4. Blazevska A., Miceva K., Stojanova B. et al., 2012. Perception of the local population toward urban forests in Municipality of Aerodrom. In: South-East European Forests, vol. 3(2), pp. 87-96.
5. Cordell H.K., 2008. The latest on trends in nature-based outdoor recreation. In: Forest History Today, vol. 2, pp. 4-10.
6. Cortinovis C., Zulian G., Geneletti D., 2018. Assessing nature-based recreation to support urban green infrastructure planning in Trento (Italy). In: Land, vol. 7(4), pp. 112.
7. De Meo I., Agnelli E.A., Graziani A. et al., 2017. Deadwood volume assessment in Calabrian pine (*Pinus brutia* Ten.) peri-urban forests: Comparison between two sampling methods. In: Journal of Sustainable Forestry, vol. 36(7), pp. 666-686.
8. De Meo I., Paletto A., Cantiani M.G., 2015. The attractiveness of forests: Preferences and perceptions in a mountain community in Italy. In: Annals of Forest Research, vol. 58(1), pp. 145-156.
9. Dhami I., Deng J., Burns R.C. et al., 2014. Identifying and mapping forest-based ecotourism areas in West Virginia – Incorporating visitors' preferences. In: Tourism Management, vo. 42, pp. 165-176.
10. Formica S., Uysal M., 2006. Destination attractiveness based on supply and demand evaluations: An analytical framework. In: Journal of Travel Research, vol. 44(4), pp. 418-430.
11. Fredman P., Boman M., Lundmark L. et al., 2012. Economic values in the Swedish nature-based recreation sector — A synthesis. In: Tourism Economics, vol. 18(4), pp. 903-910.
12. Fujisaki I., Mohammadi-Aragh M.J., Evans D.L. et al., 2007. Comparing forest assessment based on computer visualization versus videography. In: Landscape and Urban Planning, vol. 81(1), pp. 146-154.
13. Gössling S., Hickler T., 2017. Tourism and forest ecosystems. In: Gössling S, Hall CM (eds.). Tourism and global environmental change: ecological, social, economic, and political interrelationships, Routledge, New York.
14. Grilli G., Jonkisz J., Ciolli M. et al., 2016. Mixed forests and ecosystem services: Investigating stakeholders' perceptions in a case study in the Polish Carpathians. In: Forest Policy and Economics, vol. 66, pp. 11-17.
15. Gundersen V.S., Frivold L.H., 2008. Public preferences for forest structures: A review of quantitative surveys from Finland, Norway and Sweden. In: Urban Forestry and Urban Greening, vol. 7(4), pp. 241-258.
16. Horak S., Weber S., 1997. Forests as destination attractiveness factor: case study of Dalmatia (Croatia). In: Turizam/Tourism, vol. 45(11-12), pp. 275-288.
17. Hynynen J., Ahtikoski A., Siitonen J. et al., 2005. Applying the MOTTI simulator to analyze the effects of alternative management schedules on timber and non-timber production. In: Forest Ecology and Management, vol. 207(1-2), pp. 5-18.
18. Jankovska I., Straupe I., Brumelis G. et al., 2014. Urban forests of Riga, Latvia

– Pressures, Naturalness, Attitudes and Management. In: Baltic Forestry, vol. 20(2), pp. 342-351.

19. Laws E., 1995. Tourism destination management: Issues, analysis, and policies. Routledge, New York.
20. Lee C.F., Huang H.I., Yeh H.R., 2010. Developing an evaluation model for destination attractiveness: sustainable forest recreation tourism in Taiwan. In: Journal of Sustainable Tourism, vol. 18(6), pp. 811-828.
21. Leiper N., 1990. Tourist attraction systems. In: Annals of Tourism Research, vol. 17(3), pp. 367-384.
22. Mayo E.J., Jarvis L.P., 1981. The psychology of leisure travel: effective marketing and selling of travel service. CBI Publishing, Boston, MA.
23. Paletto A., De Meo I., Cantiani M.G. et al., 2013. Social perceptions and forest management strategies in an Italian alpine community. In: Mountain Research and Development, vol. 33(2), pp. 152-160.
24. Paletto A., Fagarazzi C., Grilli G. et al., 2021. Demand analysis on forest-based recreational activities. In: Journal of Environmental Accounting and Management (in press).
25. Paletto A., Guerrini S., De Meo I., 2017. Exploring visitors' perceptions of silvicultural treatments to increase the destination attractiveness of peri-urban forests: A case study in Tuscany Region (Italy). In: Urban Forestry and Urban Greening, vol. 27, pp. 314-323.
26. Pastorella F., Avdagić A., Cabaravdić A. et al., 2014. Does mountain forest characteristics influence visual appeal? A study case in an Alpine Valley in Italy. In: Proceedings International Conference "Natural resources, green technology & sustainable development", 26th-28th November 2014, Faculty of Food Technology and Biotechnology, University of Zagreb, Croatia.
27. Pelyukh O., Paletto A., Zahvoyska L., 2019. Comparison between people's perceptions and preferences towards forest stand characteristics in Italy and Ukraine. In: Annals of Silvicultural Research, vol. 43(1), pp. 4-14.
28. Reitsamer B.F., Brunner-Sperdin A., Stokburger-Sauer N.E., 2016. Destination attractiveness and destination attachment: The mediating role of tourists' attitude. In: Tourism Management Perspectives, vol. 19, Part A, pp. 93-101.
29. Ruddel S., Sampson R., Smith M. et al., 2007. The role of sustainably managed forests in climate change mitigation. In: Journal of Forestry, vol. 105(6), pp. 314-319.
30. Schejbal C., 2018. Evaluation of tourist destination attractiveness. In: Paper of the Vysoká škola logistiky o.p.s (VŠLG), Praha, Czech Republic.
31. Sevenant M., Antrop M., 2011. Landscape representation validity: A comparison between on-site observations and photographs with different angles of view. In: Landscape Research, vol. 36(3), pp. 363-385.
32. Tyrväinen L., Silvennoinen H., Kolehmainen O., 2003. Ecological and aesthetic values in urban forest management. In: Urban Forestry and Urban Greenings, vol. 1, pp. 135-149.
33. Van Raaij W.F., 1986. Consumer research on tourism: Mental and behavioral constructs. In: Annals of Tourism Research, vol. 13(1), pp. 1-9.

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM "*FOREST AND SUSTAINABLE DEVELOPMENT*"
9[TH] EDITION, 16[TH] OF OCTOBER 2020, BRASOV, ROMANIA

ANALYTIC HIERARCHY PROCESS AND BENEFIT COST ANALYSIS FOR THE SELECTION OF SUITABLE EUCALYPT RE-ESTABLISHMENT METHODS: A CASE STUDY IN KWAZULU-NATAL, SOUTH AFRICA

Muedanyi RAMANTSWANA[1,2] Michal BRINK[2]
Keith LITTLE[1] Raffaele SPINELLI[3]

Abstract: *Deciding which re-establishment methods to apply has become increasingly complex due to the expanding range of options and the numerous criteria that need to be fulfilled to support any chosen options. The objective of this study was to develop a decision model for the selection of the best method to perform different re-establishment activities, based on stakeholder preferences. The Analytical Hierarchy Process (AHP) was used in conjunction with Benefit Cost analysis to facilitate the process of selecting the best re-establishment method. Results from the case study carried out in Kwazulu-Natal on eucalypt re-establishment showed that the mechanized and semi-mechanized re-establishment alternatives were best for all criteria assessed, except for cost efficiency, where manual methods offered improved financial returns.*

Key words: *Decision-making, technology, alternative.*

1. Introduction

The main hardwood species grown commercially in South Africa are eucalypts, wattle and poplars [70]. South Africa has 521,325 ha of eucalypt plantation, of which 57.8% is located in the KwaZulu-Natal province [23]. Depending on site quality, eucalypt stands are grown over a rotation ranging from 6 to 12 years [41]. Eucalypts are commercially significant plants because they are fast growers of good form and can be used for various purposes—such as pulpwood, poles, saw timber, mining timber, biomass and essential oils [5].

Pulpwood is an important commodity for the South African economy. In 2017, the value of the pulp round wood production amounted to 6.9 billion Rands [23]. For South Africa to sustain and increase the supply of fibre, precision

[1] Nelson Mandela University, Forest Engineering, George, South Africa;
[2] University of Pretoria, Plant and Soil Science, Pretoria, South Africa;
[3] IVALSA CNR, Forest Operations, Sesto Fiorentino, Italy;
Correspondence: Muedanyi Ramantswana; email: Muedanyi.ramantswana@mandela.ac.za.

forestry is required in pulpwood re-establishment [49]. The use of technology in silviculture is important because it can improve productivity [10, 54] and decrease negative environmental impacts [32].

Globally, advancements in technology influence the way in which tasks are performed across various industries such as agriculture, mining, manufacturing, construction and forestry [15]. The introduction of new technology or innovation results in both opportunities and uncertainties [44]. In forestry, stakeholders responsible for intensively managed plantations continually make site-specific decisions regarding the best methods for site preparation, planting, weed control and fertilization [4, 54]. Moreover, they are faced with making complex evaluations regarding the choice of the most appropriate technologies so as to remain competitive and increase returns to the company [35].

According to Prisecaru [53] the complexity associated with decision-making is expected to increase as industries transition and adapt to the Fourth Industrial Revolution. Within forestry, modernisation (entails using the most up-to-date techniques and equipment to perform task) will result in technological changes, especially where digital solutions, connectivity, robotics, and big data sets are used [79].

In South Africa, most re-establishment activities are conducted manually, and include practices such as the management of harvesting residues, site preparation, planting, fertilisation, and weed control [70, 74]. Over the past decade, various new re-establishment technologies have been tested operationally (mainly associated with mulching, stump treatment, preparation of planting positions and planting), with some adopted into current practice. Examples are the preparation of a planting position through the use of a pick, earth auger, single pitting head machine, multiple pitting head machine and tractor, or dozer-pulled ripper [6, 7, 16]. The modernisation of re-establishment activities in South Africa is in response of the need to improve operator health and safety, increase productivity whilst reducing costs, improve work quality, and mitigate labour related risks [42, 50, 63, 75]. Due to the increase in available options, forestry grower companies and contractors are faced with the difficult task of having to consider numerous alternatives before selecting appropriate re-establishment methods to use in their operations.

The complexity in forestry decision making is exacerbated by multiple criteria—including economic, social, environmental, and technical factors—that have to be taken into account [52]. Furthermore, some tasks may entail diverse stakeholders (small private growers versus large corporate companies) [28], and conflicting objectives and constraints [4]. Therefore, decision support systems that incorporate multiple criteria and information from various sources are important to improve the quality of decision making in forestry.

Multi-criteria decision analysis (MCDA) is used to describe a collection of formal approaches which take explicit account of several criteria when assisting individuals or groups making important decisions [3]. Some of the most popular MCDA methods are Goal programming, PROMETHEE, ELECTRE, MACBETH, MAUT (Multi-Attribute Utility Theory), ANP (Analytical

Network process) and AHP (Analytical Hierarchy Process) [30]. Each method has its advantages and disadvantages. The Analytical Hierarchy Process is defined as a theory of prioritization that derives relative scales of absolute numbers, known as ‘priorities’, from judgements expressed numerically on an absolute fundamental scale [58]. AHP can be described as a multi-criteria optimization methodology that includes the risk factors to be considered when making a decision. It is a versatile and robust tool because it can deal with qualitative and quantitative attributes [33].

Decision support systems (DSS) such as the analytic hierarchy process (AHP) have been tested in numerous studies related to forest engineering [13, 51] and forest planning [2, 17, 31, 48]. In forest operations, DSS models have been used for making decisions about optimal harvesting methods and systems [22, 29, 68]. However, there has been no published study related to operational criteria and alternatives to assist forest stakeholders to decide on the best re-establishment methods to use.

To address this, a study was conducted to:

- Develop a decision model for selection of the best method to perform different re-establishment activities (residue management, preparation of a planting position, weeding before planting, planting, fertilising and weeding after planting) based on stakeholder preferences; and

- To use benefit cost analysis for selecting re-establishment methods that generate the highest return on investment.

2. Materials and Methods

A two-phased approach was adopted for this study. The first approach made use of AHP for the selection of the most appropriate re-establishment method based solely on the non-financial benefits thereof. Where complex decisions involving multiple facets are made, it is recommended that costs are excluded until all the associated benefits of the alternatives have been assessed, especially were decision makers may disqualify an alternative, based on the costs alone [27]. The second approach combined the results of the non-financial benefits (from the AHP model) with cost hierarchies, with output ratios analysed as described by Wedley et al. [76]. The complete decision process involved eight key steps (Figure 1).

2.1. Multi-Criteria Decision Analysis - Analytic Hierarchy Process (AHP)

For this study, the AHP method was identified as the most appropriate method based on the parameters of the method itself, the modelling effort required and the output required based on the study objectives. For AHP, the main factors considered when making a decision are first identified and then arranged in a hierarchic structure that includes (in the descending order): overall goal; criteria; sub-criteria; alternatives [57]. Analytic Hierarchy Process is based on pair wise comparisons and relies on the judgements of experts to derive priority scales (priorities are numbers associated with the nodes of an AHP hierarchy) to be used to measure intangibles in relative terms [59]. The comparisons are further structured according to a scale of absolute judgements that represent how much more one element (criteria/sub-criteria) dominates another with respect to a given attribute. The derived priority scales are multiplied by the priority of their parent nodes (upper level nodes).

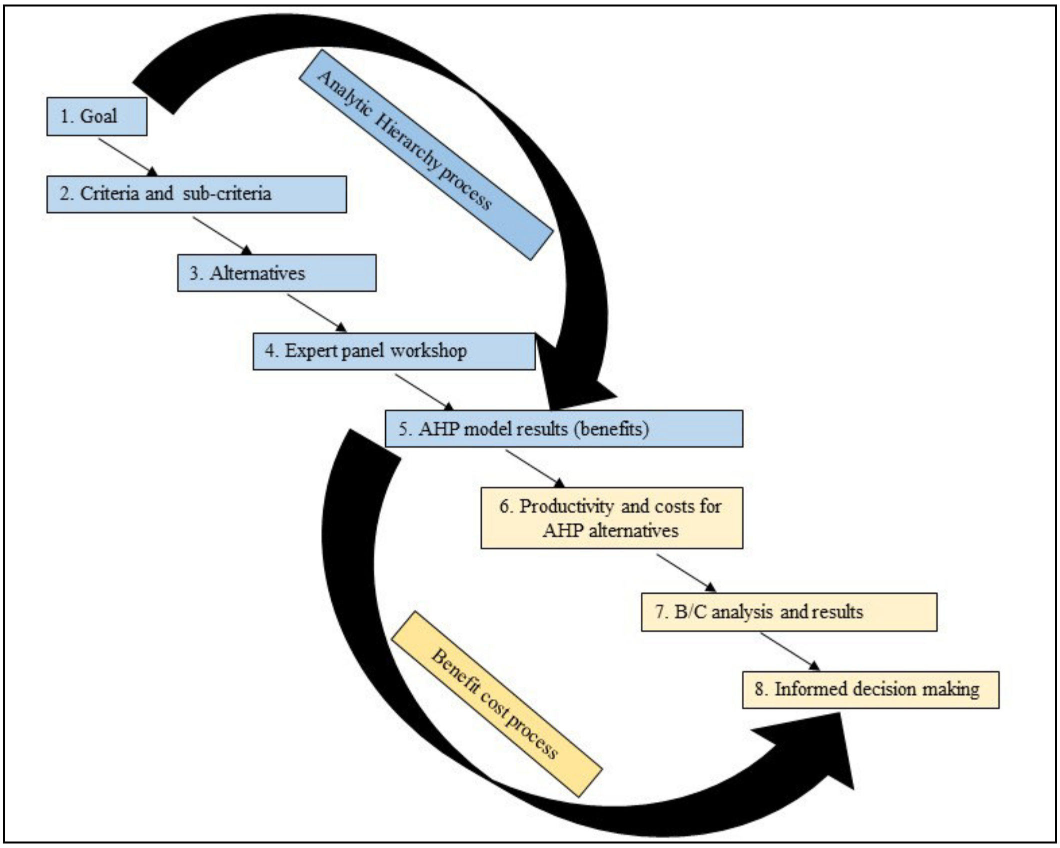


Fig. 1. *Schematic diagram of the steps followed in the decision-making process*

The fundamental scale (Table 1), which is used in AHP to make judgements, has been validated for effectiveness in many applications and through theoretical comparisons with a large number of other scales [57]. AHP has already been used successfully in forest engineering [13, 68], which further supports the method choice made by the researcher.

In this study the ratings mode was used to obtain priorities for selection of the alternative methods. The ratings mode identified priorities by establishing rating categories for each criterion and prioritised the categories by pair-wise comparison for preference. Alternatives were then evaluated by selecting the appropriate rating category for each criterion [59].

2.2. AHP Model Design

The AHP model was constructed based on key objectives provided by the experts. The model is illustrated in the form of a hierarchy value tree (Figure 2).

Table 1

The fundamental scale [57]

Intensity of importance on absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Very strong importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	Evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity, then j has the reciprocal value when compared with *i*	
Rationals	Ratios arising from scale	If consistency were to be forced by obtaining n numerical values to span the matrix

2.2.1. AHP Hierarchy Goal

Adopting the AHP developed by Saaty [59], a case study was used to illustrate the application of the decision model. The case study goal was to select the best re-establishment method for a large commercial company that grows eucalypts for pulp and paper in the KwaZulu-Natal forestry region of South Africa. The extent of the case study was limited to the collection of opinions from silvicultural experts currently active in this region. The selection of a re-establishment method can be classified as a complex decision process due to the number of factors that need to be considered (for example: ergonomic friendliness, output/ha, employment opportunities etc). The decision-making process involved evaluating all possible alternatives based on the “importance criteria”, such that the best re-establishment method(s) would be chosen.

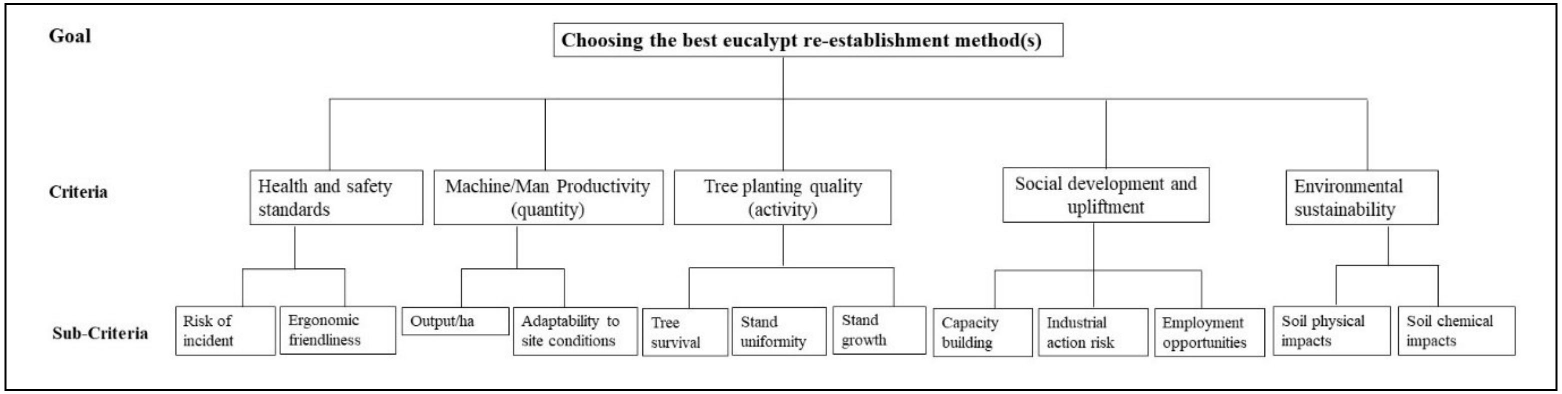


Fig. 2. *Hierarchy of decision maker's goal, criteria, and sub-criteria for selecting the best re-establishment method*

2.2.2. Importance Criteria

Five attributes of a good re-establishment method were identified by conducting a literature review and interviewing experts. These were subsequently used as main criteria and sub-criteria in this study. A benefits hierarchy was used to generate priorities for non-financial benefits of each re-establishment activity. The benefit priorities were then compared to the cost priorities to determine then the highest ratio of benefit to costs. Costs were considered as separate attribute against which the results obtained from the non-financial benefits using AHP were plotted to give the final trade-offs so as to find best re-establishment system [69].

The main criteria were:

i. Health and safety standards - referring to the safety level of the method, taking into consideration the potential health risk of the individual or team using it.
ii. Machine/man productivity - referring to the effectiveness and efficiency of the re-establishment method in terms of the output (e.g. trees planted per hour)
iii. Tree planting quality – referring to the ability of the re-establishment method to meet the tree planting specifications in terms of tree performance (survival, growth and uniformity).
iv. Social development and upliftment – referring to the effect of the method in terms of considering community needs, providing employment, empowering people and dealing with labour related risks
v. Environmental sustainability – referring to the extent to which the method resulted in a reduced impact on the site and ensured a sustainable future crop.

2.2.3. Sub-Criteria

The main criteria were divided into sub-criteria. The sub-criteria helped the experts to have a more detailed understanding of each of the main criteria and they are described in Table 2.

2.2.4. Alternatives: Re-Establishment Methods

Various methods (alternatives) within each re-establishment activity were identified by the researcher based on interviews with various experts. The alternative methods were derived from the main re-establishment activities, namely: harvesting residue management, preparation of a planting position (POPP), weeding before planting, planting, fertilising and weeding after planting (Table 3). For example, the alternative methods considered under residue management were burn, broadcast and mulch.

2.3. Decision Making Panel

Due to the lack of local scientific studies investigating relationships between re-establishment methods and the criteria for their selection, the ratings used in the AHP model were predominantly based on the experiences of the experts, research from other countries (such as Brazil [25] and Sweden [19]) and reports from company research studies. A panel of nine local experts involved in re-establishment of eucalypt plantations in KwaZulu-Natal were invited to participate in a workshop so as to rate the main and sub-criteria.

According to Ishizaka and Nemery [30], when various experts are consulted, bias present when judgements are made by one expert is eliminated. The experts who participated possessed relevant knowledge (all had greater than 10 years' experience in re-establishment) and were engaged in the following roles: grower company silviculture specialists (2), silviculture management forester (1), silviculture product and equipment manufacturers (2), contractors (CEOs) (2), business development manager (1) and researcher (1).

Table 2

Sub-criteria used for selection of the best re-establishment method

Main criteria	Sub-criteria	Description of sub-criteria
Health and safety standards	Risk of incident	Likelihood and impact of incident
	Ergonomic friendliness	Reduction in musculoskeletal disorders such as carpal tunnel, back and neck strain, and fatigue
Machine/man productivity	Output/ha	A measure of efficiency of a person or machine in converting inputs into useful outputs.
	Adaptability of the method or system	Ability to adjust to new working conditions e.g. terrain
Tree planting quality	Tree survival	Percentage mortality of plants
	Tree uniformity	Limited stand or state of being consistent e.g. Height and DBH
	Tree growth	increase in size and numbers of vegetative structures of plants
Social development and upliftment	Capacity building	Education and skills training for the work
	Industrial action risk	Labour and politically related instability
	Employment opportunities	Jobs, opportunity to secure paid work
Environmental sustainability	Soil physical impacts	Soil displacement, soil compaction and soil loss
	Soil chemical impacts	Nutrient availability and organic matter

Before the workshop, the experts were sent background information about the research and literature about the AHP method used for decision-making. At the workshop the experts were further orientated about the AHP method and the expectations (desired outcomes) for their participation in the workshop. The experts' task was to conduct pairwise comparisons to derive weightings for the main criteria and sub-criteria. The main criteria (Table 2, left column) were individually compared against each other in the form of a matrix to establish which was more important with respect to the goal of selecting the best re-establishment method.

Using the 9-point scale typical of AHP studies, the experts assessed the extent of dominance of each element over the others. When the experts could not reach consensus on a specific rating, the geometric mean [59] was used to combine their individual ratings and derive a single score. The consistency ratio of the pairwise comparison was calculated at the end of the process. When the pairwise comparison matrix is consistent, the normalized sum of each criteria score indicates how much each criteria dominates the others in relative terms. Consistency checking helps to detect possible contradictions in the pairwise entries [30]. A consistency ratio of 10% or less is considered valid for a 4 by 4 (or higher) matrix.

To normalize the data so as to obtain idealised priorities for the ratings [59], the score for each priority was divided by that of the largest of the priorities. For each re-establishment method, the total overall rating score was calculated and then compared to the overall scores for the other alternatives within the re-establishment category (activity).

Table 3

Re-establishment activity alternatives available for selecting best re-establishment methods

Activity	Residue management	Preparation of planting position	Weeding before planting	Planting	Fertilizing	Weeding after planting
Methods	Mulch Broadcast Burn	Single pitting head machine Earth auger Pick	Tractor boom spray Chemical with knapsack Manual clearing	Wasserplanzer (high water pressure planter) Tractor planter Planting tube Manual (trowel)	Fertilizer tablets Fertilizer backpacks Fertilizer fork	Tractor spray rig with lances Manual (hoe/slash) Chemical with knapsack

2.4. Benefit Cost Analysis

Equipment manufacturers and grower companies were contacted to gather cost and productivity information for the different re-establishment methods identified as alternatives (Costing assumptions Annexure 1). The South African Forestry Contractors Association (SAFCA) costing model was used to accurately estimate the costs for conducting different re-establishment methods. To ensure consistency in all costings, only direct costs were used, with indirect costs (overhead and administrative costs) excluded from the cost calculation. Furthermore, costs of material inputs such as seedlings, chemicals and fertilizer where excluded in the costings because they are standard costs regardless of re-establishment methods assessment.

The costings of each method were conducted independently of each other to allow for accurate comparisons between different methods. In reality, the cost of different re-establishment activities are costed out together to derive labour/machine rates to ensure the labour and vehicle resources are used efficiently. The same re-establishment resources (e.g. labour) can perform various activities depending on the re-establishment needs at a specific time (e.g. labour can perform pitting and broadcasting). The common cost denominator used was the cost per ha of each of the alternatives. The projects with B/C (benefit cost) ratios greater than one are considered to yield positive net benefits and they are the ones that can be undertaken [77]. The relative differences between the total AHP ratings and B/C ratios were used to graphically compare the findings.

3. Results

3.1. Using the AHP for Selecting the Best Re-Establishment Method

The weights for the main criteria and sub-criteria were derived from the pairwise comparisons scores provided by the experts (Table 4).

Table 4

Relative ranking of criteria

Criteria	**Priorities (%)**
Health and safety standards	38.7
Tree planting quality	27.6
Environmental sustainability	19.1
Machine/man productivity	9.2
Social development and upliftment	5.4
Total	**100**
Sub-criteria	***Global alternative priorities (%)***
Risk of incident	32.3
Tree survival	15.8
Soil physical impacts	9.6
Soil chemical impacts	9.6
Tree growth	7.9
Man/machine output/ha	7.7
Ergonomic friendliness	6.5
Tree uniformity	3.9
Capacity building	2.8
Employment opportunities	1.6
Adaptability of the method/system	1.5
Industrial action risk	0.9
Total	**100**

The re-establishment method associated with the highest level of health and safety standards had the highest weight (38.71%), with the need to provide social development and upliftment, the lowest weight (5.36%). A valid consistency ratio of 9% was derived from the pairwise comparisons. Amongst the sub-criteria, the level of incident risk associated with the re-establishment method had the highest weight (32.26%), and the risk of industrial action had the lowest weight (0.92%). The consistency ratios of the sub-criteria were all 0%.

By using the rating categories for each of the sub-criteria, the priority outputs were determined by pair-wise comparing them for preference. For example, the rating categories for risk of incident are high, moderate and low risk. These categories were compared for preference using the pair-wise comparison method (Table 5). Table 6 gives the corresponding numerical ratings from Table 5 for each re-establishment activity alternative.

The preferences of the decision makers involved when rating each method was sucessful in indicating the best method for each re-establishment activity (Table 7). For residue management, POPP, weeding before planting and weeding after planting, mechanised alternatives had the highest rating priorities. Based on the objective of selecting the best re-establishment method (based on the algorithm used by the researcher), the output from the model indicated the following preferred options: mulching (Figure 3a) to manage the residues, a single pitting head machine (Figure 3b) to prepare planting position, a tractor-mounted boom sprayer (Figure 3c) to apply chemical (herbicide) before planting, and tractor spray rig with lances to conduct inter-row weeding after planting (Figure 3f). The Wasserplanzer (Figure 3d) and fertilizer fork (Figure 3e) were rated as the preferred methods for planting and fertilizing respectively.

3.2. Benefit Cost Analysis

The results from the B/C analysis (Table 7) indicated that burning (Figure 3a) and manual pitting (Figure 3b) had the highest B/C ratios compared to the other options within their activity category. Of interest was that both methods (burning and manual pitting) were the second most preferred residue management and POPP method when non-financial benefits were taken into consideration. The use of a tractor-boom sprayer generated the highest B/C ratio, which was consistent with the most preferred weeding before planting method when considering non-financial benefits. Manual planting with a trowel and tubes generated the two highest B/C ratios for planting, although the Wasserplanzer method was the most preferred in terms of non-financial benefits. The application of fertilizer tablets was the most viable method for fertiliser application compared to other alternatives, although the use of fertiliser forks was the preferred option when considering non-financial benefits. When comparing weed control methods following planting, the tractor spray rig with lances method generated the highest B/C.

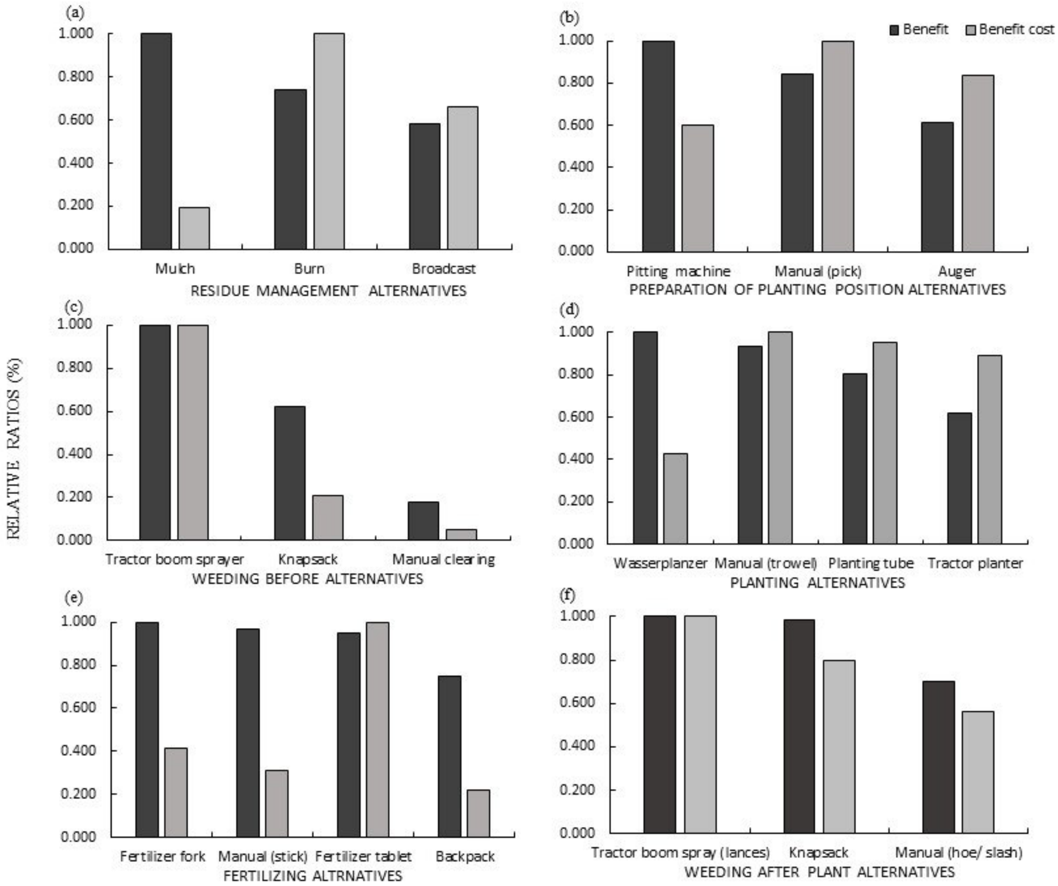


Fig. 3. *Relative non-financial benefit and benefit cost ratios for each re-establishment activity alternative:(a) Residue management (b) Preparation of a planting position, (c) Weeding before planting, (d) planting, (e) fertilizing and, (f) weeding after planting*

Table 5

Prioritised ratings categories for all criteria

Health and safety standards		Machine/man productivity		Tree planting quality			Social development and upliftment			Environmental sustainability	
Risk of incident	Ergonomic friendliness	Output/ha	Adaptability	Survival	Uniformity	Growth	Capacity building	Industrial action risk	Employment opportunities	Soil physical impacts	Soil chemical impacts
High risk	Good	High	High	>90%	Highly uniform	High m^3/ha	Advanced	High likelihood	>5 people	High risk	High risk
0.071	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.071	1.000	0.085	0.085
Moderate risk	Moderate	Moderate	Medium	70–89%	Moderately uniform	Moderate m^3/ha	Intermediate	Moderate likelihood	2-5 people	Moderate risk	Moderate risk
0.304	0.298	0.304	0.411	0.304	0.402	0.316	0.454	0.304	0.500	0.298	0.298
Low risk	Poor	Low	Low	<70%	Poor uniformity	Low m^3/ha	Basic	Low likelihood	1 person	Low risk	Low risk
1.000	0.084	0.071	0.168	0.079	0.111	0.074	0.087	1.000	0.148	1.000	1.000

Table 6

Numerical values for alternative ratings for each re-establishment category

ACTIVITY	SUB-CRITERIA / METHOD	Risk of incident	Ergonomic friendliness	Output/ha	Adaptability to site conditions	Tree survival	Stand uniformity	Tree growth	Capacity building	Industrial action risk	Employment opportunities	Soil physical impacts	Soil chemical impacts
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Residue management	Burn	0.304	0.084	1.000	1.000	0.295	1.000	1.000	0.454	0.070	1.000	0.084	0.084
	Broadcast	0.304	0.084	0.070	0.411	0.295	0.401	1.000	0.087	0.304	1.000	1.000	1.000
	Mulch	1.000	1.000	0.070	0.411	0.295	1.000	0.315	1.000	1.000	0.147	1.000	1.000
Preparation of planting position	Manual (pick)	1.000	0.084	0.070	1.000	1.000	1.000	1.000	0.087	0.304	1.000	1.000	1.000
	Auger	0.304	0.084	0.304	0.411	1.000	1.000	1.000	0.454	0.304	0.499	1.000	1.000
	Single pitting head machine	1.000	0.298	1.000	0.411	1.000	1.000	1.000	1.000	1.000	0.147	1.000	1.000
Weeding before planting	Manual clearing	0.070	0.084	0.070	1.000	0.079	0.110	0.073	0.087	0.304	1.000	1.000	1.000
	Chemical application with knapsack	0.304	0.084	0.304	1.000	1.000	1.000	1.000	0.454	0.304	0.499	0.298	1.000
	Tractor boom sprayer	1.000	0.298	1.000	0.167	1.000	1.000	1.000	1.000	1.000	0.147	0.298	1.000

Table 6 (continuation)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Planting	Manual (hoe/trowel)	1.000	0.084	0.070	1.000	1.000	1.000	0.315	0.454	0.070	1.000	1.000	1.000
	Planting tube	1.000	0.298	0.304	1.000	0.295	0.401	0.315	0.454	0.070	1.000	1.000	1.000
	Tractor planter	0.304	1.000	1.000	0.411	0.295	0.401	0.315	0.4543	0.304	0.499	1.000	1.000
	Wasserplanzer	1.000	0.298	0.304	0.411	1.000	1.000	0.315	1.000	0.304	0.499	1.00	1.000
Fertilising	Manual (stick/trowel)	1.000	0.084	0.070	1.000	1.000	1.000	1.000	0.087	0.070	0.499	1.000	1.000
	Fertilizer fork	1.000	0.298	0.304	0.411	1.000	1.000	1.000	0.087	0.070	0.499	1.000	1.000
	Fertilizer backpack	0.304	0.298	0.304	0.411	1.000	1.000	1.000	0.454	0.304	0.499	1.000	1.000
	Fertilizer tablet	1.000	0.298	1.000	1.000	1.000	1.000	0.315	0.087	0.304	0.147	1.000	1.000
Weeding after planting	Manual (hoe/ slash)	0.070	0.084	0.070	1.000	0.295	0.401	0.315	0.087	0.070	1.000	1.000	1.000
	Chemical application with knapsack	0.304	0.084	0.304	1.000	0.295	0.401	0.315	0.454	0.070	0.499	1.000	1.000
	Tractor spray rig with lances	0.304	0.298	0.304	0.411	0.295	0.401	0.315	0.454	0.070	0.499	1.000	1.000

Table 7. *Re-establishment methods: non-financial benefits calculated using the AHP method and benefit cost ratios*

Activity	**Method**	**Non financial benefit (AHP)**	**Rate/ha**	**Normalised costs**	**Benefit cost ratio**
Residue management	Mulch	0.430	R 4 770.23	0.759	0.949
	Burn	0.318	R 687.96	0.109	4.854
	Broadcast	0.252	R 828.00	0.132	3.199
Preparation of planting position	Single pitting head machine	0.407	R 2 302.31	0.513	1.798
	Manual (pick)	0.344	R 1 174.32	0.261	2.981
	Auger	0.249	R 1 015.40	0.226	2.494
Weeding before planting	Tractor boom sprayer	0.557	R 274.09	0.132	6.928
	Knapsack	0.346	R 818.46	0.393	1.441
	Manual clearing	0.098	R 990.42	0.475	0.336
Planting	Wasserplanzer	0.413	R 3 576.13	0.487	1.467
	Manual (trowel)	0.385	R 1 419.13	0.193	3.448
	Planting tube	0.331	R 1 285.02	0.175	3.278
	Tractor planter	0.256	R 1 060.70	0.144	3.069
Fertilizing	Fertilizer fork	0.370	R 548.30	0.244	3.152
	Manual (stick)	0.359	R 711.61	0.317	2.357
	Fertilizer tablet	0.352	R 216.55	0.096	7.592
	Backpack	0.278	R 769.35	0.343	1.686
Weeding after planting	Tractor spray rig with lances	0.372	R 729.23	0.287	1.135
	Knapsack	0.367	R 898.56	0.354	0.908
	Manual (hoe/ slash)	0.261	R 909.39	0.358	0.637

4. Discussion

Based on the criteria tested in this study, the AHP and B/C analysis were successful as decision aids for the selection of the best re-establishment method from a range of options (The corresponding author can be contacted for a copy of the Decision support tool). The AHP method applied in this study focused on identifying the non-financial benefits of various re-establishment methods and the benefit cost analysis included cost considerations in order to identify the method(s) that generate the highest return on investment. To create a valid reference for the points discussed in the following paragraphs, it is important to highlight a limitation of the study. It is imperative to recognise that the outcomes could be different if a different group of people were used and if the objectives of the landowner were different. For example, the panel comprised of people with technical and business expertise and did not have a social expert who could have influenced the priority weighting of the social development and upliftment criteria.

4.1. AHP

When ranking the criteria priorities, the re-establishment method's ability to meet health and safety requirements was ranked the highest (38.71%) by the experts. For large corporate companies; employee work-related injuries lead to legal liabilities and to a poor reputation. This can make it difficult for a company to attract and retain skilled employees, adversely affect company morale and have significant cost implication [73]. In South Africa, some large corporations are mechanising silviculture activities to reduce risks related to performing physically demanding work [11].

In this study, the risk of an incident occurring was rated by the experts as the highest (32.26%) amongst the sub-criteria. Thissub-criteria was highly rated because of the strict safety regulations surrounding safety and the need for punctual adherence to safety regulations whenever an incident occurs. Literature findings indicate that silviculture workers are at risk of various occupational health issues, some of which are similar to those in harvesting operations and some of which are more specific to the task being performed [38, 72]. Musculo-skeletal problems are associated with carrying out certain manually orientated work. For example, the manual planting of trees requires prolonged and repetitive non-neural postures, which can cause musculoskeletal problems. According to Sullman and Byers [66], manual planting can be classified as hard continuous work. Further, silviculture crews are exposed to a range of potentially harmful chemicals, such as fertilizers, pesticides, lubricants, diesel and petroleum fuels and their emission. Although mechanising forest operations may significantly improve safety, the use of machines also introduces new hazards [55], such as neck, shoulder, arm and hand problems, caused by an operator using control levers, machine keyboards and display units [21, 71].

Tree planting quality was ranked the second highest (27.62%) criteria, and the ability of a re-establishment method to achieve the best tree survival rate was considered the second highest (15.85%)

sub-criteria. According to Löf et al. [36], low seedling performance (survival and tree growth) may lead to significant financial losses. The experts who participated in this study agreed that tree survival is critical for the sustainability of any grower company because poor survival during the establishment phase can lead to sub-optimal use of resources on the site and, ultimately, to a lower timber yield at rotation end. Using mechanised re-establishment methods does not guarantee positive tree performance (survival, tree growth and uniformity). This is based on the results from numerous studies conducted on various re-establishment activities globally (refer to examples provided below).

When comparing various manual and mechanised land preparation methods in re-establishing hardwoods in South Africa, Smith et al. [61] found insignificant differences in survival and tree growth. In fact, complete site preparation by machines led to a reduction in growth in some sites. More studies conducted in Europe found that the effects of the use of mechanised site preparation on tree performance varied considerably, depending on the site and type of treatment. Generally, reported responses were positive [37, 67].

When comparing manual and mechanised planting in Ireland, Nieuwenhuis and Egan [47] found that manual planting was significantly better than mechanised planting for plant positioning and planting quality, although mechanised planting was within the acceptable range. Furthermore, no differences in tree growth were found in the first growing season between manual and mechanised planting operations in the same study. In Sweden, Ersson 19] observed that seedlings planted by the planting machines showed higher survival rates than manually planted seedlings. However, another study [39] found that survival rates in mechanised planting varied, depending on the re-establishment area, machine and planting period.

Tree planting quality is closely linked to environmental sustainability, which in this study comprised of two sub-criteria (soil physical impact - 9.6%, and soil chemical impacts - 9.6%). The experts agreed that an optimal re-establishment method should have a reduced negative impact on both physical and chemical components of the soil. According to Nambiar [45], to maintain site productivity, the soil quality must be preserved and the impacts of management on resource depletion should be minimized. The impacts of soil disturbance on forest productivity have been well studied, with several studies showing loss in productivity because of topsoil disturbance [23, 45, 62]. The use of heavy site preparation equipment can cause soil compaction, churning, rutting, mixing, displacement, and soil removal, which in turn can limit tree root growth because of damage to soil physical, chemical, and biological properties [43]. According to Löf et al. [36], the relationship between a re-establishment method and tree performance is difficult to quantify because of the interactions of the method selected on soil physical and soil chemical properties that affect plant performance.

The man/machine productivity criteria was ranked fourth (9.31%) by the expert participants. The experts believed that achieving high man/machine productivity without health and safety, tree planting quality and environmental sustainability would result in detrimental inefficiencies to the whole re-establishment system. In the past in South Africa, due to the availability and low cost of labour, there has been little focus on significantly improving man/machine productivity in re-establishment operations [64] which contrasts with a much greater attention to productivity in harvesting operations. However, over the past decade new semi- and fully-mechanised technologies have been developed to improve the output/ha of various re-establishment methods, mainly due to labour related factors such as high turnover [7, 14].

Pitting is an example of an activity that has experienced a significant increase in productivity because of progressive mechanisation. When pitting on similar conditions, a person using a pick can achieve 494 pits/shift [46], a single operator using an earth auger can achieve 1243 pits/shift [60] and a single pitting head machine can complete 2500 pits/shift [65].

However, mechanised options do not always produce a higher output compared to manual methods. For example, when clearing harvesting residues, a mulcher can clear 2.5 ha/shift [26] whilst a burning team of six people can clear an area of 4.2ha ha/shift (based on 1.4 man days per ha). Regardless of whether an activity is performed manually or mechanically, the man/machine productivity maybe directly affected by factors such as terrain (ground conditions, ground roughness and slope), weather, residues (slash and stumps), stand density, delays (personal, operational or mechanical) and human factors (such as experience) [20, 34, 56].

The ability of a re-establishment method to provide social development and upliftment (5.4%) was ranked the least important criteria. The experts consulted in this study argued that the main goal of a corporate company is to make a return in the most sustainable and cost-effective manner possible. However, companies need to be conscious of the socio-economic needs of the local communities, such as employment needs and capacity building. Globally, the involvement and consideration of local communities in forest management decisions is becoming more important [1, 18]. This is because local communities may be current or future land owners [78], dependent on the land and forest resource (e.g. employment, biomass resources, practice of culture and heritage needs etc.) [9], and impacted negatively or positively by changes in forest operations. According Marchi et al. [40], sustainable forest operations should promote socially acceptable and responsible activities which enhance community values and wellness. In South Africa, most re-establishment activities are still predominantly performed manually, although there is slow progression to semi- and fully-mechanised methods. In certain instances mechanisation of traditionally manual operations can lead to some job losses. However, new work opportunities can be created through enterprise development programmes within the surrounding communities [12]. According to Charnley [9], decision makers in forest re-establishment and management need to consider the advantages and disadvantages of socio-economic changes (e.g. mechanisation) to local people to avoid displacement and exclusion of already poor communities living in and around the plantation areas.

4.2. Benefit-Cost

The study found that when considering the non-financial benefits of different re-establishment method, mechanised options within each category were found to be the best. This outcome was due to favourable ratings (based on criteria) associated with mechanised options compared to manual alternatives. For example, the experts' rating found mulching to be the best residue management method because when mulching the operator works from an ergonomically friendly cab which has a lower health and safety risk compared to burning and broadcasting slash manually. The experts believed that mulching yields excellent tree survival, highly uniform stands and moderate tree growth. However, they considered mulching as a low production method because of the hectares that can be cleared in a day [8]. In terms of social development, the experts believe that mulching provides the operator with advanced skills and training and the likelihood of industrial actions is low even though the employment opportunities are very low. Due to the organic matter mulch retained on the site, the experts considered mulching as a low impact method in terms of risk on the physical and chemical components of the soil. The AHP findings were based on this specific expert group's knowledge and landowner objectives. Irrespective of the non-financial benefits of a method, the costs had to be considered because in reality some methods may possess good overall benefits but may not be economically viable.

In general, mechanised alternatives are associated with improved safety and productivity compared to manual ones. However mechanised alternatives are more capital intensive. When including cost considerations in the rankings, then burning became the preferred option among all residue management techniques, because of its cost effectiveness. Even though mulching is safer, its cost-effectiveness is restricted by the high capital costs and low machine productivity. The benefit cost analysis results of the POPP activity were similar to those of residue management. Although manual pitting is ergonomically unfriendly and not as productive as its mechanised counterpart, it was the preferred method because of the lower costs (almost half) of the mechanised options. The earth auger method had the lowest cost, but the poor non-financial benefits generated by the method made it unfavourable.

The outcomes of the benefit cost analysis of the weeding before planting activity showed that the tractor mounted boom sprayer method was preferred. Despite the high capital costs, the operational costs (cost per ha) of using this method were found to be less than those of the knapsack and manual clearing methods. The high B/C ratio of the tractor boom sprayer can be attributed to the high productivity, which dilutes the fixed costs. The selection of this method over the other alternatives needs to be carried out after careful planning and consideration of its limitations (especially terrain). Where suitable, a combination of this method with other alternatives may be considered. Manual planting with a trowel and tubes generated the highest B/C ratios. When considering non-financial benefits, the Wasserplanzer method would be preferred. However, because this planting method incorporates the POPP process, it incurred higher costs and had lower productivity compared to other conventional planting methods. When deciding on the preferred planting method to use, the decision maker needs to assess the Wasserplanzer method holistically.

The results of the benefit cost analysis of the fertilization activity indicated that the use of fertilizer tablets generates the highest returns compared to the other methods. The high B/C ratio can be attributed to the relatively low costs because fertilizer tablets are integrated with the planting activity, whereas conventional fertilization methods (granular fertilizer) occur as a separate activity after planting. When selecting the preferred fertilization method, the decision maker needs to consider the suitability of using fertilizer tablets compared to using granular fertilizer to remedy nutritional needs of the site.

The outcomes of the benefit cost analysis of the weeding after planting activity showed that the tractor spray rig with lances method was preferred. This method generated the greatest non-financial benefits and the highest return on investment. Despite high capital costs, the operational cost (cost per ha) of using this method was found to be low because of the high productivity, which dilutes the higher fixed costs. Although the model developed in this study considers the tractor spray rig with lances method as the best, the decision maker needs to consider the limitations of using this method (especially terrain). Where applicable, a combination of this method with other alternatives may be considered. It is important to note that if labour costs increase drastically in future the outcomes of the B/C ratios may shift from manual to mechanised alternatives.

5. Conclusions

The study proved that AHP combined with benefit cost analysis can be used by forestry decision makers to select the best re-establishment method for eucalypt plantations. The criteria and sub-criteria weightings guide the decision maker in prioritizing important characteristics that need to be fulfilled by the alternatives. Results from the illustrative example showed that when considering non-financial benefits only, the mechanised and semi-mechanised re-establishment alternatives were the best, mainly because they acquired better ratings compared to manual methods based on the specified criteria. However, when it came to the benefit cost analysis, manual methods in all re-establishment activities except weeding before and after planting generated better returns economically because of the generally lower cost of performing manual activities.

In South Africa, re-establishment activities performed manually are progressively being mechanised. Decisions to change from manual to semi- or fully-mechanised methods are complex and require in-depth analysis of the various factors involved. The AHP decision model will assist decision makers to choose the best re-establishment methods to use in their plantations based on their specific criteria (risk factors) and landowner objectives. Although AHP is reliable, it requires accurate data to guide the decision maker correctly. Scientific data on a specific subject area may not be available which may lead to unreliable or incorrect predictions. However, this shortcoming is overcome by using a well experienced panel of experts who can make well informed recommendations where there are data gaps.

Future research on this subject area would benefit from focussing on using different expert groups and comparing their findings. In addition, the AHP could be compared to other multi-criteria decision analysis (MCDA) tools.

References

1. Alden Wily L., Mbaya S., 2001. Land, people and forests in eastern and southern Africa at the beginning of the 21st Century. The impact of land relations on the role of communities in forest future Nairobi, IUCN-EARO.
2. Ananda J., Herath G., 2003. The use of Analytic Hierarchy Process to incorporate stakeholder preferences into regional forest planning. In: Forest Policy and Economics, vol. 5(1), pp. 13-26.
3. Belton V., Stewart T., 2002. Multiple criteria decision analysis: an integrated approach. Springer Science & Business Media.
4. Blagojević B., Jonsson R., Björheden R. et al., 2019. Multi-Criteria Decision Analysis (MCDA) in forest operations – An introductional review. In: Croatian Journal of Forest Engineering, vol. 40(1), pp. 15.
5. Brooker I., 2002. Botany of eucalypts. In: Coppen J.J.W. (ed.): Eucalyptus: The Genus Eucalyptus. Taylor and Francis Inc, USA and Canada, pp. 1-28.
6. Chapman C., 2012. Mechanised pitting machine in the spotlight. In: SA Forestry Magazine. Green Forest Media, Hillcrest.
7. Chapman C., 2015. Mechanisation changing the face or forestry. In: SA Forestry. Green Forest Media, Hillcrest.
8. Chapman C., 2018. Mulching gaining ground. In: SA Forestry Magazine. Green Forest Media, Hillcrest.
9. Charnley S., 2006. Industrial plantation forestry: Do local communities benefit? In: Journal of Sustainable Forestry, vol. 21(4), pp. 35-57.
10. Choudhry H., O'Kelly G., 2018. Precision forestry: A revolution in the woods. Advanced technologies could improve forest management significantly. What areas are most promising, and how can forestry companies start their digital transformation? McKinsey and Company, Singapore, pp 11.
11. Clarke J., 2012. Investigation of working conditions of forestry workers in South Africa. Final Report. Department of Agriculture, Forestry and Fisheries, Republic of South Africa, 104 p.
12. Clarke J., 2018. Job creation in agriculture, forestry and fisheries in South Africa. An analysis of employment trends, opportunities and constraints in forestry and wood products industries. Institute for Poverty, Land and Agrarian Studies (PLAAS), Working paper no. 52, 56 p.
13. Coulter E.D., Coakley J., Sessions J., 2006. The analytic hierarchy process: A tutorial for use in prioritizing forest road investments to minimize environmental effects. In: International Journal of Forest Engineering, vol. 17(2) pp. 51-69.
14. Crane J., 2017. A decade of developing novel mechanised silviculture equipment. Wood Southern Africa and Timber Times

Malnor, Johannesburg, Republic of South Africa.

15. Cunningham S., 2018. World Economic Forum and the fourth industrial revolution in South Africa. In: Levin S. (ed.): Tips Research Report for Department of Trade and Industry. Trade and Industry Policy Strategies, Republic of South Africa, 31 p.
16. da Costa D., 2013. Modernisation and the effect on silviculture. Presented at the Focus on Engineering conference, 6 November, 2013, Lythwood Lodge Lidgetton, KwaZulu-Natal.
17. Diaz-Balteiro L., Romero C., 2008. Making forestry decisions with multiple criteria: A review and an assessment. In: Forest Ecology and Management, vol. 255(8-9), pp. 3222-3241.
18. Enters T., Durst P., Brown C., 2003. What does it take? The role of incentives in forest plantation development in the Asia-Pacific region. In: Unasylva, vol. 54, pp. 11-18.
19. Ersson B.T., 2014. Concepts for mechanized tree planting in southern Sweden. Doctoral Thesis. Swedish University of Agricultural Sciences, Umeå, Sweden.
20. Ersson B.T., Laine T., Saksa T., 2018. Mechanized tree planting in Sweden and Finland: Current state and key factors for future growth. In: Forests, vol. 9(7), 370, 12 p.
21. Gallis C., 2013. Increasing productivity and controlling of work fatigue in forest operations by using prescribed active pauses: a selective review. In: Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering, vol. 34(1), pp. 103-112.
22. Ghaffariyan M., Brown M., 2013. Selecting the efficient harvesting method using multiple-criteria analysis: A case study in south-west Western Australia. In: Journal of Forest Science, vol. 59(12), pp. 479-486.
23. Godsmark R., Oberholzer F., 2019. The South African forestry and forest products industry 20187. In: Forestry South Africa (ed). Forestry South Africa, Pietermaritzburg, Republic of South Africa, 164 p.
24. Grey D., Jacobs E., 1987. The impact of harvesting on forest site quality. In: South African Forestry Journal, vol. 140(1), pp. 60-66.
25. Guerra S.P.S., Soler R.R., Sereghetti G.C. et al., 2019. An evaluation of the economics and productivity of fully mechanised tree seedling planting in Brazil. In: Southern Forests: A Journal of Forest Science, vol. 81(3), pp. 281-284.
26. Gumede M., 2019. Mulcher productivity. In: Ramantswana M. (ed.), TIgercat Mucher productivity edn, George.
27. Haas R., Meixer O., 2005. An illustrated guide to analytic hierarcy process. Boku, Vienna, Austria.
28. Haider L.H.W., 2001. Fair and effective decision making in forest management planning. In: Society and Natural Resources, vol. 14(10), pp. 873-887.
29. Horodnic S.A., 2015. A risk index for multicriterial selection of a logging system with low environmental impact. In: Environmental Impact Assessment Review, vol. 51, pp. 32-37.

30. Ishizaka A., Nemery P., 2013. Multi-criteria decision analysis: methods and software. John Wiley & Sons, West Sussex, UK.
31. Kangas J., Kangas A., Leskinen P. et al., 2001. MCDM methods in strategic planning of forestry on state-owned lands in Finland: applications and experiences. In: Journal of Multi-Criteria Decision Analysis, vol. 10(5), pp. 257-271.
32. Kovácsová P., Antalová M., 2010. Precision forestry–definition and technologies. In: Šumarski List, vol. 134(11) pp. 603-610.
33. Kurttila M., Pesonen M., Kangas J. et al., 2000. Utilizing the analytic hierarchy process (AHP) in SWOT analysis - A hybrid method and its application to a forest-certification case. In: Forest Policy and Economics, vol. 1(1), pp. 41-52.
34. Längin D., Ackerman P., Olsen G., 2010. Introduction to ground based harvesting systems and methods. South African ground based harvesting handbook Pietermaritzburg: Forest Engineering South Africa and Institute for Commercial Forestry Research, pp. 23-43.
35. Lawrence A., Stewart A., 2011. Sustainable forestry decisions: on the interface between technology and participation. In: Mathematical and Computational Forestry and Natural Resource Sciences, vol. 3(1), pp. 42-52.
36. Löf M., Dey D.C., Navarro R.M. et al., 2012. Mechanical site preparation for forest restoration. In: New Forests, vol. 43, pp. 825-848.
37. Löf M., Rydberg D., Bolte A., 2006. Mounding site preparation for forest restoration: survival and short term growth response in *Quercus robur* L. seedlings. In: Forest Ecology and Management, vol. 232(1-3), pp. 19-25.
38. Lovelock K., Houghton R., 2017. There's silviculture and there's logging – that's two industries". WorkSafe New Zealand, New Zealnd, 128 p.
39. Luoranen J., Rikala R., Smolander H., 2011. Machine planting of Norway spruce by Bracke and Ecoplanter: an evaluation of soil preparation, planting method and seedling performance. In: Silva Fennica, vol. 45(3), pp. 341-357.
40. Marchi E., Chung W., Visser R. et al., 2018. Sustainable Forest Operations (SFO): A new paradigm in a changing world and climate. In: Science of the Total Environment, vol. 634, pp. 1385-1397.
41. Maree B., Kotze H., du Toit B., 2012. Silviculture of industrial *Eucalyptus* and *Acacia* plantations in South Africa. In: Bredenkamp B., Upfold S. (eds.). South African Forestry Handboook, South African Institute of Forestry, Pretoria, pp. 141-154.
42. McEwan A. Steenkamp J., 2014. Silviculture modernization in the South African forestry industry. In: Proceedings of the Second International Congress of Silviculture, 26th-29th November, Florence, Italy, pp. 822-826.
43. Miller R.E., Colbert S.R., Morris L.A., 2004. Effects of heavy equipment on physical properties of soils and on long-term productivity: A review of literature and current research. Technical Bulletin no. 0887. Research

Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

44. Nair C., 2003. Forests and forestry in the future: what can we expect in the next fifty years. XII World Forestry Congress: Area C-People and Forests in harmony. FAO, Quebec City, Canada.
45. Nambiar E., 1996. Sustained productivity of forests is a continuing challenge to soil science. In: Soil Science Society of America Journal, vol. 60(6), pp. 1629-1642.
46. NCT Forestry Co-operative Limited, 2006. Productivity Manual. Sum Silviculture Operation. NCT, KwaZulu-Natal.
47. Nieuwenhuis M., Egan D., 2002. An evaluation and comparison of mechanised and manual tree planting on afforestation and reforestation sites in Ireland. In: International Journal of Forest Engineering, vol. 13(2), pp. 11-23.
48. Nilsson H., Nordström E.-M., Öhman K., 2016. Decision support for participatory forest planning using AHP and TOPSIS. In: Forests, vol. 7(5), p. 100.
49. Pallett R.N., 2005. Precision forestry for pulpwood re-establishment silviculture. In: Southern African Forestry Journal, vol. 203(1), pp. 33-40.
50. Parker R.J., 2013. A field investigation into the impact of task demands on worker responses in the South African Forestry Silviculture Sector. Department of Human Kinetics and Ergonomics. Rhodes University, Grahamstown, Republic of South Africa, 183 p.
51. Parsakhoo A., Hosseini S.A., 2009. Formulation of the truck selection process for secondary transportation in Hyrcanian Forests. In: World Applied Sciences Journal, vol. 6(2), pp. 283-288.
52. Perez-Rodriguez F., Rojo-Alboreca A., 2012. Forestry application of the AHP by use of MPC© software. In: Forest Systems, vol. 21(3), pp. 418-425.
53. Prisecaru P., 2016. Challenges of the fourth industrial revolution. In: Knowledge Horizons Economics, vol. 8(1), pp. 57-62.
54. Rubilar R.A., Allen H.L., Fox T.R. et al., 2018. Advances in silviculture of intensively managed plantations. In: Current Forestry Reports, vol. 4, pp. 23-34.
55. Rummer R.B., Taylor S., Veal M., 2003. New developments in operator protection for forest machines. In: Proceedings of 2nd Forest Engineering Conference, May 12-15, Växjö, Sweden, pp. 60-66.
56. Saarinen V.-M., 2006. The effects of slash and stump removal on productivity and quality of forest regeneration operations - Preliminary results. In: Biomass and Bioenergy, vol. 30(4), pp. 349-356.
57. Saaty T.L., 1990. How to make a decision: the analytic hierarchy process. In: European Journal of Operational Research, vol. 48(1), pp. 9-26.
58. Saaty T.L., 2000. Fundamentals of decision making and priority theory with the analytic hierarchy process. RWS publications. Pittsburg, USA.
59. Saaty T.L., 2008. Decision making with the analytic hierarchy process. In: International Journal of Services Sciences, vol. 1(1), pp. 83-98.
60. Shuttleworth B., 2012. Mechanical establishment operations auger

pitting and planter tube Midlands 2012. Forestry Solutions, Pietermaritzburg, pp. 1-13.

61. Smith C., Little K., Norris C., 2001. The effect of land preparation at re-establishment on the productivity of fast growing hardwoods in South Africa. In: Australian Forestry, vol. 64(3), pp. 165-174.

62. Smith C.W., 2003. Does soil compaction on harvesting extraction roads affect long-term productivity of Eucalyptus plantations in Zululand, South Africa? In: The Southern African Forestry Journal, vol. 199(1), pp. 41-54.

63. Steenkamp J., 2007. The effect of HIV and AIDS on the viability and management of forestry contracting businesses in South Africa. Nelson Mandela Metropolitan University, Republic of South Africa.

64. Steenkamp J., 2017. Modernisation of Silviculture is imminent and unstoppable. SA Forestry magazine Green Forest Media, Hillcrest, USA.

65. Steenkamp J., 2020. Productivity of the MPAT. In: Ramantswana M. (ed), George, p. 1.

66. Sullman M.J., Byers J., 2000. An ergonomic assessment of manual planting *Pinus radiata* seedlings. In: International Journal of Forest Engineering, vol. 11(1), pp. 53-62.

67. Sutton R., 1993. Mounding site preparation: A review of European and North American experience. In: New Forests, vol. 7, pp. 151-192.

68. Talbot B., Tarp P., Nitteberg M., 2014. Selecting an appropriate excavator-based yarder concept for Norwegian conditions through the analytic hierarchy process. In: International Journal of Forest Engineering, vol. 25(2), pp. 113-123.

69. Thengane S.K., Hoadley A., Bhattacharya S. et al., 2014. Cost-benefit analysis of different hydrogen production technologies using AHP and Fuzzy AHP. In: International Journal of Hydrogen Energy, vol. 39(28), pp. 15293-15306.

70. Theron K., 2000. Establishment. In: Owen D. (ed.). South African Forestry Handbook. 4th Edn. South African Institute of Commercial Forestry Research, Pretoria, Republic of South Africa.

71. Tobisch R., Walker M., Weise G., 2005. Scientific review of forest machine technical ergonomics. Institutionen för Skogens Produkter och Marknader, no. 2, Uppsala, Sweden, 185 p.

72. Trites D.G., 1992. Ergonomics of tree planting work among British Columbia forest workers. Theses - School of Kinesiology. Simon Fraser University, USA, 96 p.

73. Tsioras P.A., 2012. Promotion of safety in forest operations. In: Advanced Research in Scientific Areas, December, pp. 3-7.

74. Viero P., du Toit B., 2012. Establishment and regeneration of eucalypt, pine and wattle stands. In: Bredenkamp B. and Upfold S. (ed.). 5th Edn. South African Forestry handbook. 5th Ed. Southern African Institute of Forestry, Pretoria, Republic of South Africa, pp. 99-105.

75. von Benecke D., 2015. Toward a new business model for modernised silviculture forestry practices in South Africa: An abductive study. Graduate School of Business. University of Cape Town, Republic of South Africa.

76. Wedley W.C., Choo E.U., Schoner B., 2001. Magnitude adjustment for AHP benefit/cost ratios.In: European Journal of Operational Research, vol. 133(2), pp. 342-351.
77. Wedley W.C., Choo E.U., Wijnmalen D.J., 2003. Benefit/Cost priorities: achieving commensurability. In: Proceeding of the Annual Conference of the Administrative Sciences Association of Canada – ASAC, June 14-17, 2003, Halifax, Nova Scotia.
78. Whiteman A., Wickramasinghe A., Piña L., 2015. Global trends in forest ownership, public income and expenditure on forestry and forestry employment. In: Forest Ecology and Management, vol. 352, pp. 99-108.
79. Xu M., David J.M., Kim S.H., 2018. The fourth industrial revolution: Opportunities and challenges. In: International Journal of Financial Research, vol. 9(2), pp. 90-95.

ANNEXURE 1. MACHINE COST ASSUMPTIONS

Note: Only direct costs included in the costing – excludes overheads

1. Forest resource

Annual re-established area for costing	1200 ha
Average compartment size	40 ha
Tree spacing (planting density)	3 x 2m (1 666 trees ha^{-1})
Average slope	Flat (0 – 20%)

2. Capital costs

Interest	10% (prime 11/12/2019) +3% = 13% (South African Reserve bank 2019)
Exchange rate	1$ = R14.75 (11/12/2019)
Profit and overheads	0%
Licensing and insurance	2% of machine price per year
Resale value	10% - forestry equipment 20% - labour carriers
Depreciation period	60 months

3. Running cost of machines

Diesel price	R14.59 /litre
Diesel consumption	MPAT: 3/mhr (38KW) Tractor: 16l/mhr (65KW) Mulcher Tigercat M726: 35l/mhr (275KW)
Oil price	R62/litre
Oil consumption	MPAT: 5% Tractor: 7% Mulcher Tigercat M726:5%
Repair and maintenance cost* *Repair and maintenance cost used in the costings include **total cost** of purchasing and running a full workshop and doing daily infield maintenance on the machines. However, the repair and maintenance figure does not distinguish between labour cost, back-up vehicle cost and cost of spare parts	80%

4. Running cost of machines (cont'd)

Equipment purchase costs	MPAT: R1 144 478 Tractor New Holland 6610 : R546 560 Planting trailer ANCO GP3000: R335 000 Mulcher Tigercat M726: R6 603 900 Tools Stihl earth Auger: R11 500 Planting backpack unit: R2 695 Fertilizer forks (galvanized): R2 000 Fertilizer backpacks R7 000 Tractor boom spray rig R50 000 Tractor mounted windbox rig R95 000
	MPAT: Tracks Life: 4000mhrs, R30 000 (set) Tractor New Holland T160: Front tyres 6 000/tyre @ 4000 hrs Rear tyres R10 217/tyre @ 4000 hrs Trailer ANCO GP3000: R335 000 Trailer tyres 9 000/tyre @ 6000 hrs Mulcher Tigercat M726: Life: 6000mhrs, R250 000 (set)
Equipment life	15 000hrs
Machine moves per year	10 moves @ R5,000 per move, MPAT only Assumption is that tractor, trailer and wheeled mulcher will drive to various compartments

5. Wages and work days

Wages per month	Manual labour R3 500 (R18/hr national minimum wage 2019) Machine operator R7 800
Production days per year	260
Shifts per day (9-hour shifts)	Manual operations x 1 shift Tractor trailer planter x 1 shift MPAT x 2 shifts Mulcher x 1 shifts
Days per working week	5 days

6. Productivity

(i) Manual operations	*Productivity assumptions**
○ Residue management • Burning • Broadcast	Average man-days per hectare (m/ha): ○ 1.4 m/ha ○ 2.4 m/ha
○ Preparation of a planting position • Manual (pick) • Earth auger	 ○ 4.2 m/ha ○ 2.4 m/ha
○ Weeding before planting • Manual clearing • Chemical application with knapsack	 ○ 2.4 m/ha ○ 2.1 m/ha
○ Planting • Manual (hoe/trowel) • Planting tube	 ○ 3.9 m/ha ○ 3.3 m/ha
○ Fertilizing • Manual (stick/trowel) • Fertilizer fork • Fertilizer backpack • Fertilizer tablet	 ○ 1.9 m/ha ○ 1.4 m/ha ○ 1.9 m/ha ○ 1 m/ha
○ Weeding after plant • Manual (hoe/slashing) • Chemical application with knapsack /(cones)	 ○ 3.1 m/ha ○ 2 m/ha / 2.8m/ha

(ii) Semi- and fully-mechanised operations	*Productivity assumptions*
○ Residue management • Mulch	 ○ 2.5 ha/ shift
○ Preparation of planting position • MPAT single pitting head machine	 ○ 1.5 ha/shift (2500 plants/ shift)
○ Weeding before planting • Tractor-mounted boom spray	 ○ 3.92 ha/shift
○ Planting • Tractor-trailer planter	 ○ 5.94 ha/shift (9902 trees)
• Wasserplanzer	○ 1.73 ha/shift (2884 trees)
○ Weeding after plant • Tractor-mounted windbox	 ○ 7.3 ha/shift (0.82 m/ha)

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM "*FOREST AND SUSTAINABLE DEVELOPMENT*"
9TH EDITION, 16TH OF OCTOBER 2020, BRASOV, ROMANIA

ANTLER SIZE AND FORM IN RELATIONSHIP WITH CRANIAL ARCHITECTURE IN RED DEER (*CERVUS ELAPHUS L.*) A CASE STUDY IN THE CURVATURE CARPATHIANS

George SÎRBU[1,2] Dieter SIMON[2] Ovidiu IONESCU[1,2] Cezar SPĂTARU[1,2] Andreea SÎRBU[3]

Abstract: *The study has been conducted on 66 specimens of adult red deer (Cervus elaphus L.). The skulls belong to specimens harvested in the hunting season 2017-2018, but also originate from trophy collections with origin in the Curvature Carpathians. Eight trophy variables were selected for analysis, among which 13 cranial variables belong to the four cranial areas, 6 on the dorsal face, 2 on the lateral face, 2 on the ventral face and 3 on the occipital face. The sample analyzed after determining the age has been divided into 3 classes: 4-6 years, 7-9 years and over 10 years. For the investigations, a method of descriptive and multivariate statistical analysis has been used to highlight the relationships. The descriptive analysis of these variables highlighted the degree of variability of this sample, a starting point in their comparison with other populations. The analysis of correlations and regressions highlighted the links established between these variables, generating through simple and multiple regression mathematical expressions that reveal these links. The discriminant analysis performed between the three age groups highlighted the variables with discriminant value for both the cranial and trophy variables, the correct classification of the discriminant score being 85.96% per total experiment. In order to create a clearer picture of these aspects, it is necessary to study more data, especially for the category of young specimens.*

Key words: *Cervus, cranial variables, Curvature Carpathians, statistical analysis, trophy variables.*

[1] SCDEP Brasov - Wildlife Department, National Institute for Research and Development in Forestry "Marin Drăcea", Brasov, Romania;
[2] Faculty of Silviculture and forest engineering, Transylvania University of Brasov, Romania;
[3] Faculty of Veterinary Medicine, USAMV Bucharest, Romania;
Correspondence: George Sîrbu; email: sirbugeorgeeugen@gmail.com.

1. Introduction

The population of deer (*Cervus elaphus* L.) in Europe over the last 20 years has increased significantly from 1.1 to 1.7 million specimens, as well the harvest quotas, but managerial models indicate that poor administration at the level of the age classes can induce certain populations to an uncontrolled growth and, finally, to decay [3]. The deer population of Romania belongs to the subspecies *Cervus elaphus hippelaphus*, Erxl., 1877, or *Cervus elaphus montanus*, Botezat (1935) quoted by [5], and is located in the center of the area of *Cervus elaphus* L. [1], populating the chain of the Eastern, Southern and Western Carpathians and presenting important habitat fragmentation. Reduced numbers are also found in hilly and lowland areas [5]. It is considered the largest representative of subspecies in Europe, being close in size to the skull and skeleton to those of the Canadian elk deer [9].

The surface of the hunting funds in Romania that consists of the deer species, amounts to over 22 million ha, the harvest quotas of the last decade showing a significant increase in terms of numbers and population dynamics [27]. The evaluation of trophies, a historical practice, has generated over time the emergence of evaluation formulas with continuous improvements, culminating in 1930 with the establishment of the CIC, an organization that will develop new formulas with application instructions and thus eliminate non-essential aspects or subjectivism [20].

An important aspect is the fall and growth of the antlers because, every year, the males lose their horns and at about 10 days their growth begins at a speed of about 2 cm/day [4]. This process of rapid regeneration, in addition to annually determining unique individual morphologies, can bring important variations in the shape of the antlers, usually expressed by asymmetry in parts of the antlers, both numerically and morphologically [17].

The analysis of the main components (PCA) applied on 40 cranial markers of eight species of deer and aiming at the variation of the skull shape, shows that these components are closely correlated with the size of the cranial centroid but also with morphometric elements (height) and individual weight [15].

A detailed descriptive image of several physical characteristics specific to a population, is provided by cranial morphometric elements, even if genetically the epistatic implications cannot be highlighted [10, 11, 14], in general the mammalian skull being a powerful tool in biogeographic, phylogenetic and systematic studies [12], cited by Markov [13].

Last but not least, the economic aspect of obtaining valuable trophies should be mentioned as well. Knowing the population characteristics and applying a coherent management, arises in obtaining valuable trophies characterized by the size and symmetry of the antlers [19].

The present study aims to analyze the relations that are established between certain variables in the cranial architecture and variables of the trophy.

2. Material and Methods
2.1. Study Area

The study has been conducted on a number of 66 specimens of adult deer collected in the hunting season 2017-2018, as well as from private collections of trophies. Their origin is the region of the Curvature Carpathians with its respective groups, the area of the external Curvature (Figure 1) - Vrancea Mountains, Buzău Mountains, Siriului Mountains, Ciucaș Mountains, Gârbova Mountains, Bârsa Mountains, and the internal Curvature area: Bodoc Mountains, Baraolt Mountains, Breţcu Mountains, Perşani Mountains [18].

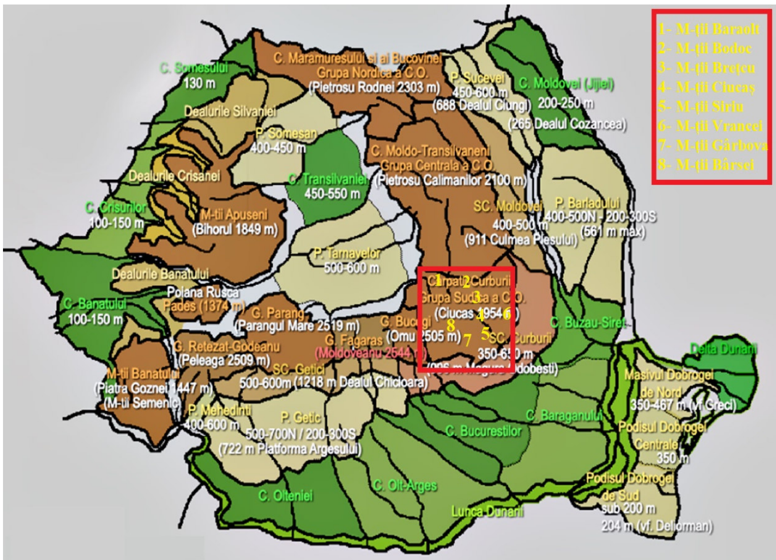


Fig. 1. *Distribution of the analyzed sample [28]*

2.2. Selection of Variables

Eight variables of the trophy have been selected, variables with high importance in its structure and evaluation (Table 1). The 13 cranial variables belong to the 4 regions, according to the model proposed by Pelabon and Breukelen [17], respectively, the dorsal region, the ventral region, the lateral region and the occipital region, being selected following the cranial architecture and the role of its bones - shape and support (Table 2), ultimately arising 21 variables that have been studied.

Because the sample contains specimens of different ages, for each of them the age was determined exactly, using the method of analysis of the secondary cement layers of the premolar I of the upper jaw [19], or mandible [21]. Following this operation, the sample was divided into three age classes: class I aged 4-6 years, class II aged 7-9 years and class III aged 10 years and over. The measurements have been performed with mechanical and electronic calipers, roulette, the accuracy being 0.1 mm for cranial variables and 1 mm for trophy variables (Appendix 1).

The cranial variables are presented in Appendix 2.

Table1

Trophy variables

No	Acronym	Explanation of the variables	Unit
1	LP	The average of main beams length	mm
2	LRO	The average of brow tines length	mm
3	LRM	The average of tray tines	mm
4	DCF	The average diameter of the front cylinder	mm
5	CR	The average circumference of coronets	mm
6	NRC	Number of tines	-
7	D_{max}	Maximum spread of beams	mm
8	D_{min}	Minimum spread of beams	mm

Table 2

Cranial variables, expressed in millimetres

No	Cranial region	Acronym	Explanation of the variables
1	Dorsal face	P-Br	Prostheon-Bregma – length of the skull from the prostheon to the point of intersection of the frontal, parietal, and occipital sutures
2		N-Br	Nasion-Bregma – length of the skull from the point of intersection of the nasal bones with the frontal bones (P) and the point of intersection of the frontal, parietal and occipital sutures (Br)
3		Fs-Fs	Frontostenion-Frontostenion – minimum width of the skull, measured at the base of the front cylinders
4		Eu-Eu	Euryon-Euryon – maximum width of the neurocranium
5		Op-Br	Opisthokranion-Bregma – length of the neurocranium, measured from the posterior extremity of the occipital bone to the point of intersection of the frontal, parietal and occipital sutures
6		P-Op	Prostheon-Opisthokranion – maximum length of the skull
7	Lateral face	Zl-P	Zygolacrimale-Prostheon – length of the viscerocranium
8		Zl-Op	Zygolacrimale-Opistohokranion – length of the neurocranium
9		N-St	Staphilyon-Nasion – viscerocranium height
10		Sph-Br	Sphenobasion-Bregma – neurocranium height
11	Occipital face	Ot - Ot	Otion-Otion – width of occipital bones
12		Con-Con	The measured width of the outer edges of the occipital condyles
13		Op - O	Opistokranion-Opistion – maximum height of the occipital face

2.3. Statistical Data Analysis

The statistical analysis has been performed using the Statistics 8 package [6. The investigation techniques used consist of the descriptive technique - mean, standard error of means, standard deviation and coefficient of variation, regression analysis and the multivariate technique - discriminant analysis. The values of these variables have been processed by means of descriptive statistical indices, and the structure and intensity of the links by means of correlation coefficient. Multiple regression analysis applied between cranial and trophy variables has been generated a series of interesting regression equations. Discriminant analysis applied to the third groups highlighted the variables with discriminant power.

3. Results

3.1. Trophy and Cranial Variables

Using the descriptive technique, the trophy and cranial variables have been processed separately on the three age classes, obtaining the main statistical indicators, respectively, mean (M), standard deviation (SD), standard mean error (Std. err. of mean) and coefficient of variation (CV%) (Table 3).

Comparing the three distributions through the coefficient of variation, the following aspects can be outlined: the LP variable for group I presents a variation of 16.5%, almost double compared to the other two groups. This variation at an early age can be attributed to the fact that the process of antlers growth is related to environmental conditions and significantly influenced by genetic variation.

The variables LRO and LRM show similar variations for groups I and III, slightly higher for group II, suggesting a strong genetic variation with rapid evolutionary syncopes for the first two groups, where the development of the defining elements of the rods is maximum, followed by a plateau.

The variables DCF and CR show for group I slightly more pronounced variations than groups II and III; these differences are determined by the genetic factor involved in the development of the antlers.

The variations of the variables NRC could be a result of a differentiated development, the genetic fingerprint being defining for the advanced ages. D_{max} shows larger variations for group I, suggesting that the rod growth process is active, whereas for the other groups it is almost complete.

D_{min} with variations of over 30% for all three groups, suggests that the genetic factor is practically responsible for the shape of the antlers and together with D_{max} define the shape of the trophy as a whole.

Regarding the cranial variables, there is a variability of less than 10%.

Suggesting a proportional, balanced development that defines cranial architecture, it can be observed in the case of these cranial elements, an accentuated variability of group I at certain bone processes as a result of ontogenetic development, also slightly more accentuated variations at groups II and III as a result of a completed ontogenetic process, these being in fact features with the help of which the so-called ecotypes can be characterized and identified, within a population.

Table3

Descriptive statistics of variables

Variable	Group I				Group II				Group III			
	M	SD	CV	Std.err.	M	SD	CV	Std.err	M	SD	CV	Std.err
LP	868,75	143,33	16,50	41,38	1070,14	71,20	6,65	12,59	1111,89	69,86	6,28	14,89
LRO	302,83	56,93	18,80	16,43	348,96	78,20	22,41	14,28	372,94	50,45	13,53	10,76
LRM	265,71	47,15	17,74	13,61	321,06	68,78	21,42	12,16	349,27	61,91	17,73	13,20
DCF	40,41	3,92	9,70	1,13	49,27	3,38	6,85	0,60	54,59	3,55	6,50	0,76
CR	194,83	31,83	16,34	9,19	245,31	22,66	9,24	4,01	252,07	19,43	7,71	4,14
NRC	4,92	1,00	20,26	0,29	7,34	1,88	25,56	0,33	9,14	2,14	23,47	0,46
D_{max}	692,50	122,00	17,62	35,22	848,91	113,26	13,34	20,02	899,55	121,50	13,51	25,90
D_{min}	478,08	145,71	30,48	42,06	595,09	183,38	30,82	32,42	600,45	230,24	38,34	49,09
P-Br	387,88	22,48	5,79	6,78	404,78	15,42	3,81	2,77	407,06	16,15	3,97	3,44
N-Br	141,83	12,55	8,85	3,62	146,55	14,57	9,94	2,57	148,94	13,22	8,88	2,82
Fs-Fs	125,00	6,01	4,80	1,73	129,48	5,99	4,63	1,06	133,09	5,86	4,40	1,25
Eu-Eu	107,82	4,98	4,62	1,44	108,91	4,27	3,92	0,75	111,09	4,78	4,30	1,02
Op-Br	97,48	7,21	7,40	2,08	100,82	7,40	7,34	1,31	103,23	10,21	9,90	2,18
P-Op	458,77	22,41	4,88	6,76	473,97	15,93	3,36	2,86	478,31	17,87	3,74	3,81
Ot-Ot	140,08	6,55	4,68	1,89	149,75	6,31	4,21	1,17	152,32	6,85	4,50	1,50
Con-Con	79,73	3,04	3,81	0,92	79,00	3,55	4,49	0,66	80,65	3,10	3,84	0,69
Op-O	63,29	3,98	6,29	1,20	64,83	4,19	6,46	0,78	66,55	6,76	10,15	1,51
Zl-P	271,67	14,69	5,41	4,43	279,75	11,72	4,19	2,11	281,70	10,97	3,89	2,34
Zl-Op	217,48	7,93	3,65	2,29	221,73	16,51	7,45	2,92	224,89	8,69	3,86	1,85
N-St	101,75	5,46	5,36	1,65	105,89	5,82	5,49	1,06	110,49	5,14	4,66	1,12
Sph-Br	105,41	4,48	4,25	1,35	108,53	4,88	4,50	0,89	112,51	4,90	4,35	1,07

Note: M - mean, SD - standard deviation, CV - coefficient of variation (%), Std.err. - standard error of mean.

Given that most of the variables analyzed show a variability of less than 30%, the sample reveals homogeneity.

3.2. Relationship between Trophy Variables and Cranial Architecture

The intensity of the connections between the trophy variables and those of the cranial architecture has been achieved using the simple correlation, through the simple correlation coefficient (Table 4), at a probability of transgression of 5%. The correlation matrix has been concluded for each group.

Analyzing the correlation matrix for group I, we can observe three significant positive correlations for the first variable of the trophy, for the second - two, while the third variable does not correlate with any cranial variable. The variable DCF correlates with 3 cranial variables, CR with 2, NRC with 5 variables. The diameter of D_{max} does not obtain significant correlations, and D_{min} correlates with a single cranial variable.

For the first variables of the trophy, respectively LC, LRO, DCF, the correlations with the cranial processes P-Br, Ot-Ot, Zl-Op, P-Op, can be explained using the architectural relationship and cranial symmetry necessary for the development process. For the variable CR, following the same reasoning, the symmetry points on cranial regions change. NRC, moreover, with the most connections, suggests that the weight of the trophy by summing its elements this time imprints a volumetric symmetry.

Group II shows a lower number of significant correlations between the two categories of variables. Thereby, the variable LP and D_{max} correlate with a single cranial variable, the variables LRO, LRM, DCF and CR with two variables, whilst D_{min} and NRC do not correlate with any cranial variable.

For group II, the links LP, D_{max} with Con-Con, as well as LRO with N-Br and Zl-P suggest that, at these ages, the trophy weight close to the maximum somewhat changes the center of gravity, the development of bone processes being correlated with this fact. LRM with P-Br and Sph-Br processes is based on the same reasoning. The links between DCF and CR with positioning near the Fs-Fs process can be explained by the fact that it is practically responsible for the growth and symmetry of the antlers. D_{max} and Con-Con is obviously a relationship of symmetry and balance, the Con-Con process being located at the insertion of the cervical vertebrae in the neurocranium having an essential role in support.

Group III presents an interesting situation, meaning that significant negative correlations appear between the two categories of variables. The variables LRO and LRM correlate significantly negatively with N-Br and Sph-Br, respectively D_{max} with Con-Con, and the D_{min} variable with 5 variables, respectively P-Br, P-Op, Ot-Ot, Zl-P and N-St. These negative correlations can be explained by the fact that from a certain age there is a relative withdrawal of certain cranial processes compared to the dimensions of the trophy, the averages of these processes with independent value decrease, while the averages of the trophy elements increase.

Table 4

Matrix correlation of variables by groups

Groups	Variables	P-Br	N-Br	Fs-Fs	Eu-Eu	Op-Br	P-Op	Ot-Ot	Con-Con	Op-O	Zl-P	Zl-Op	N-St	Sph-Br
I	LP	**0,698***	0,055	0,352	0,588	-0,445	0,633	**0,858***	0,022	0,065	**0,686***	0,494	0,192	0,159
	LRO	0,630	0,291	0,099	0,179	0,330	**0,745***	0,600	0,280	0,422	**0,714***	0,628	0,604	-0,036
	LRM	0,623	0,163	0,295	-0,191	0,296	0,647	0,224	0,358	0,317	0,557	0,662	0,022	0,096
	DCF	**0,730***	-0,235	0,347	0,643	-0,167	0,645	**0,670***	0,147	0,310	**0,681***	0,368	0,283	0,156
	CR	0,311	-0,334	0,321	-0,082	**0,672***	0,441	0,060	0,366	**0,910***	0,244	0,288	0,439	0,076
	NRC	**0,698***	0,059	0,362	-0,030	0,441	**0,745***	0,535	**0,761***	0,530	0,647	**0,715***	0,333	**0,718***
	D_{max}	0,407	-0,185	-0,089	0,348	0,286	0,321	-0,004	0,194	0,246	0,366	0,089	0,216	0,043
	D_{min}	0,257	-0,017	0,079	0,041	**0,865***	0,339	-0,112	0,317	0,620	0,247	0,249	0,472	-0,037
II	LP	0,311	0,294	0,135	0,256	0,059	0,323	0,297	**0,484***	0,220	0,272	0,119	0,235	0,207
	LRO	0,028	**0,492***	-0,075	0,096	-0,121	0,023	-0,161	0,022	-0,128	-0,185	**0,389***	-0,090	0,049
	LRM	**0,395***	0,244	0,089	0,249	-0,125	0,309	0,190	0,107	0,115	0,208	-0,170	0,259	**0,391***
	DCF	0,273	0,103	**0,395***	0,054	0,275	0,306	**0,392***	0,219	-0,039	0,379	-0,123	0,266	0,301
	CR	0,201	0,221	**0,506***	-0,014	0,095	0,218	0,165	0,349	-0,115	0,238	-0,148	**0,443***	0,185
	NRC	0,332	0,125	0,132	0,232	0,159	0,326	0,362	0,040	0,017	0,371	0,104	0,161	0,186
	D_{max}	0,219	0,144	-0,067	0,058	0,159	0,313	0,341	**0,393***	0,365	0,206	-0,038	0,303	0,252
	D_{min}	0,212	0,029	-0,082	0,025	-0,171	0,160	0,118	0,170	0,218	0,090	-0,099	0,277	0,301
III	LP	0,359	0,070	0,298	0,420	0,072	0,439	0,255	0,202	0,068	**0,526***	0,007	-0,103	-0,154
	LRO	-0,267	**-0,589**^{0}	0,000	-0,193	0,106	-0,275	0,307	0,007	-0,119	-0,300	0,054	0,078	0,125
	LRM	0,125	0,079	0,136	0,260	-0,208	0,020	-0,293	-0,039	0,141	0,138	-0,310	-0,004	**-0,497**^{0}
	DCF	-0,024	0,150	0,397	0,195	0,260	0,130	0,307	0,155	-0,190	0,009	0,041	-0,100	0,435
	CR	0,028	-0,129	**0,532***	0,343	**0,584***	0,323	0,412	**0,504***	-0,208	0,272	0,235	0,015	0,383
	NRC	0,405	0,213	0,353	0,381	0,127	0,390	0,028	0,230	-0,008	**0,541***	-0,087	0,365	-0,133
	D_{max}	-0,211	-0,208	0,022	-0,165	-0,184	-0,300	-0,422	**-0,456**^{0}	0,373	-0,234	-0,347	-0,348	-0,000
	D_{min}	**-0,494**^{0}	-0,252	0,113	-0,377	-0,034	**-0,513**^{0}	**-0,534**^{0}	-0,403	0,246	**-0,470**^{0}	-0,214	**-0,537**^{0}	-0,012

Note: significant coefficient of positive correlation; ^{0} significant coefficient of negative correlation; probability of transgression α = 0,05%.

Significantly positive correlations are attained between LP and Zl-P, CR and Fs-Fs, Op-Br, Con-Con, NRC and Zl-P. The variable CR positively correlated with the Fs-Fs, Op-Br and Con-Con processes, as in the case of group II can be interpreted in the same way.

The variable DCF does not correlate significantly with any cranial variable.

Another approach in investigating the association between trophy variables and cranial variables was the use of multiple linear regressions applied to the sample groups. The forward stepwise method has been used in the regression calculation, and the significance of the partial coefficients has been established for a transgression probability α = 0.05%.

For group I, a single multiple linear regression equation has been validated, respectively, between the LOR variable and the 7 cranial variables (P-Op, P-Br, Zl-P, N-St, Zl-Op, Fs-Fs and Sph-Br).

For group II, seven equations of multiple linear regression have been validated, respectively one between the variable LP and one cranial variables (Con-Con) the second between LRO and 3 cranial variables (N-Br, Zl-Op, ZlP), the third between LRM and one cranial variables (P-Br), the fourth between DCF and 2 cranial variables (Fs-Fs, Ot-Ot), the fifth between CR and 2 cranial variables (Fs-Fs, Con-Con), the sixth between NRC and 1 cranial variable (Ot-Ot) and the seventh between D_{max} and 5 cranial variables (P-Op, Con-Con, Sph-Br, Fs-Fs, P-Br).

For group III, eight equations of multiple linear regression have been validated, respectively one between the variable LP and 1 cranial variable (Zl-P), the second between LRO and 4 cranial variables (Ot-Ot, N-St, Zl-P, N-Br) the third between LRM and 1 cranial variable (Zl-P), the fourth between DCF and 1 cranial variables(N-Br), the fifth between CR and 2 cranial variables(Op-Br, Sph-Br), the sixth between NRC and 5 cranial variables(Zl-P, Fs-Fs, Con-Con, P-Op), the seventh between D_{max} 1 cranial variable(Op-O) and the eigth between D_{min} and 2 cranial variables (N-St, Ot-Ot). The regression results are presented in Table 5.

3.3. Discriminant Analysis

By applying this method of multivariate technique, an attempt has been made, a priori, to determine to what extent the trophy and cranial variables have discriminant capacity for the three groups of the sample.

In this regard, 21 variables have been introduced in the statistical model (8 trophy variables and 13 cranial variables). Of the 21 variables introduced in the model, 13 variables have been included, and 8 variables have been excluded. Of the 13 variables in the model applying statistics F and Wilks' Lambda, 6 variables have been validated (Table 6).

Discriminant functions, in this case two, have been tested for significance using the Chi square test (Table 7).

Table 5

Multiple Regession Result

Groups	Variable	Multiple R	p	The shape of the equation
I	LOR	0,9999	0,00226	LOR = - 397,19 + 4,48(P-Op) - 5,50(P-Br) + 2,58(Zl-P) - 0,78(N-St) - 0,37(Zl-Op) - 0, 30(Fs-Fs) - 0,19(Sph-Br)
II	LP	0.5567	0,0096	LP = - 95,707 + 0,531(Con-Con)
	LRO	0,7098	0,0091	LRO = 156,939 + 0,507(N-Br) + 0,480(Zl-Op) – 0,37 (Zl-P)
	LRM	0,6073	0,0103	LRM = - 204,699 + 0,942(P-Br)
	DCF	0,6260	0,0068	DCF = - 265,103 + 0,407(Fs-Fs) + 0,346(Ot-Ot)
	CR	0,6878	0,0013	CR = - 284,112 + 0,502(Fs-Fs) + 0,334(Con-Con)
	NRC	0,4099	0,0310	NRC = - 11,327 + 0,410(Ot-Ot)
	D_{max}	0,7795	0,0040	D_{max} = - 1764,023 + 2,13(P-Op) + 0,498(Con-Con) + 0,473(Sph-Br) – 0,31(Fs-Fs) – 2,10(P-Br)
III	LP	0,6081	0,0197	LP = 481,397 + 0.639(ZL-P)
	LRO	0,8852	0,0083	LRO = 367,593 +0,576(Ot-Ot) +0,599(N-St) – 0.52(Zl-P)- 0,85(N-Br)
	LRM	0,6169	0,0483	LRM = 1048,942 – 0.43(Sph-Br)
	DCF	0,8070	0,0363	DCF = -18,336 + 0,840(N-Br)
	CR	0,8070	0,0064	CR = 287,589 + 0,476(Op-Br) + 0,424(Sph-Br)
	NRC	0,8888	0,0070	NRC = - 42,157 +2,46(Zl-P) +0,897(Fs-Fs) +0,488(N-St) -0,70(Con-Con) -2,3(P-Op)
	D_{max}	0,7271	0,0415	D_{max} = 2526,602 + 0,485(Op-O)
	D_{min}	0,7251	0,0017	D_{min} = 5764,289 – 0,49(N-St) -0,49(Ot-Ot)

Table 6

The discriminant function analysis summary – bold marked values are significant

N=56	N of vars in model: 13; Grouping,3 grps, Wilks' Lambda: 10733 approx. F (26,82)=6,4728 p< 0000					
	Wilks' Lambda	Partial Lambda	F-remove	p-level	Toler.	1-Toler.
DCF	**0,1363**	**0,7872**	**5,542**	**0,0074**	**0,5095**	**0,4905**
CR	**0,1604**	**0,6690**	**10,143**	**0,0003**	**0,4570**	**0,5430**
LP	**0,1271**	**0,8446**	**3,772**	**0,0314**	**0,5856**	**0,4144**
Con-Con	**0,1285**	**0,8352**	**4,045**	**0,0249**	**0,5352**	**0,4648**
N-St	0,1209	0,8880	2,585	0,0876	0,7819	0,2181
Fs-Fs	0,1098	0,9779	0,463	0,6327	0,6583	0,3417
Zl-P	0,1217	0,8818	2,747	0,0759	0,0980	0,9020
NRC	0,1152	0,9315	1,508	0,2334	0,6943	0,3057
Ot-Ot	0,1189	0,9026	2,211	0,1224	0,4291	0,5709
Sph-Br	**0,1243**	**0,8637**	**3,236**	**0,0496**	**0,6466**	**0,3534**
P-Br	**0,1352**	**0,7940**	**5,320**	**0,0088**	**0,0477**	**0,9523**
P-Op	0,1229	0,8731	2,980	0,0619	0,0493	0,9507
Op-Br	0,1205	0,8904	2,523	0,0926	0,3107	0,6893

Table 7

Chi square test - bold marked values are significant

Function	Eigen-value	Canonical R	Wilks'Lambda	Chi-Sqr.	df	p-level
0	**3,511716**	**0,882244**	**0,107332**	**104,8959**	**26**	**0,000000**
1	**1,065042**	**0,718156**	**0,484252**	**34,0821**	**12**	**0,000655**

The determination of the degree of discrimination between the three groups, achieved by the two canonical functions, is expressed by the canonical averages of the variables (Table 8).

Analyzing the data of Table 8, it can be observed that the canonical function 1 has a discriminante value between group 1 and groups 2 and 3, the canonical function 2 having a discriminante value only between groups 1 and 3. The graphical expression of the two functions is presented in Figure 2.

Table 8

Means of canonical variables

Group	Canonical function 1	Canonical function 2
I	-4,07450	-0,47851
II	0,42302	1,01409
III	1,26245	-1,15369

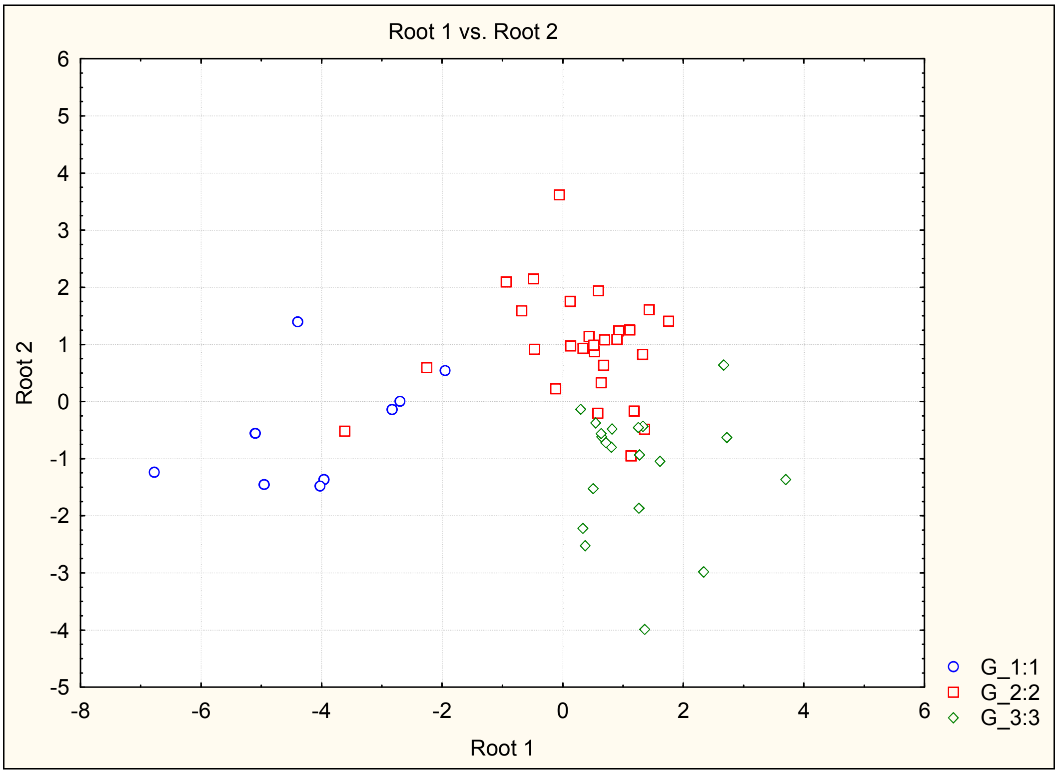


Fig. 2. *Scatterplot of canonical scores*

In regard to the probable classification, the inaccurate classification for the three groups and for the entire sample analyzed are presented in Table 9.

It can be observed that for group I the classification has been done correctly in proportion of 88.88%, out of the 9 cases one being inaccurately enclosed. In group II the classification has been done correctly in proportion of 82.14%, out of the 28 cases 5 being incorrectly classified, respectively 2 in group I and 3 in group III. In group III the classification has been done correctly in proportion of 90.00%, out of the 20 cases 2 being incorrectly classified, respectively 2 in group II. In the entire sample, the classification has been generated correctly in proportion of 85.96%.

Table 9

Observed classifications and predicted classifications

Groups	Percent correct	Gr. I p=,16071	Gr. II p=,48214	Gr. III p=,35714
I	88,88889	8	1	0
II	82,14286	2	23	3
III	90,00000	0	2	18
Total	85,96491	10	26	21

4. Discussion

The status of the subspecies and the systematic position of the deer in Romanian Carpathians is controversial topic [6]. Aspects related to morphology, weight, coat, size and characteristics of the trophy, applied in comparison to other subspecies in Western Europe, led some researchers of the time to consider that the Romanian deer population consists of two subspecies, namely *Cervus elaphus montanus* and *Cervus elaphus campestris*, (Botezat 1903) [23], more or less accepted hypotheses. Thus, a taxonomic classification specific to different authors appears - *Cervus elaphus carpathicus* (Tatarinov, 1956) [22], *Cervus vulgaris campestris* (Groves and Grubb 2011) [25], *Cervus elaphus panoniensis* (Banwell, 1997) [24]. Danilkin [7] states that the Carpathian deer is a form of transition between the Western European deer (*Cervus elaphus elaphus*) and the Caucasian deer (*Cervus elaphus maral*) [6].

The results of the genetic analyzes somewhat explain the controversies mentioned, disapproving some of the statements. In this sense, the genetic integrity of the Carpathian forms was confirmed through the distribution of the haplotype and the genetic distance [8], thus refuting the origin of the ancestral model suggested by Geist [9].

The genetic analyzes performed and, implicitly, the theories subsequently formulated, must be analyzed with caution, considering that in the IXth century and the first part of the XXth century massive populations were settled in Austria, Germany, Hungary and the Czech Republic during 1870-1918. Bradvarovic [2] with the aim of improving the quality of trophies, respectively the number of branches of the crown. Also worth mentioning are the 18 colonization centres in Romania and 3 in Serbia, where genetic material (males and females) has been distributed in almost the entire Carpathian chain, subcarpathians and certain hilly and rugged areas in the west, north-east, centre and southern Romania in the period 1960-2003 [2].

The analysis of the trophy variables reveals from the point of view of variation an interesting sedimentation at least at group level. These seemingly insignificant variations at the regional level can provide information on these characteristics, thus outlining an overview. Through the average and the coefficient of variation as statistical indicators, the trophy variables can be compared at national level, but also at European level. The same statistical indicators applied to cranial variables serve the same goals. The characterization of a population under these aspects is indicated to be performed by age classes, knowing that a simple general arithmetic mean applied to the individuals of the population can generate errors. Moreover, a further investigation on the quality and management of this population being relatively difficult to accomplish.

The correlations between the two categories of variables show that they are more numerous in the category of young deer than in the medium and large category, suggesting a link between the development of cranial bones and that of the horns, versus a stopping and the beginning of the regression of certain elements at a given time. Of course, a large number of specimens are needed for such studies, taking into account the fact that at the population level there is individual variation as an expression of genetic inheritance, on the other hand and the influence of ecological factors.

An interesting aspect compounds the regression equations obtained. It is observed that the group of young deer performs a single multiple regression equation in which 7 cranial variables are involved as explanatory factors for the LOR variable, the multiple correlation coefficient having a high significance. The other two groups perform multiple regressions between almost all trophy variables and cranial variables, thus suggesting that with age, more or less close but significant connections are made between the variables. In this context, we consider that an in-depth analysis of the cranial architecture, consisting of their regions and bones and the elements of the trophy, is necessary.

The discriminant analysis highlights three trophy variables with discriminant value between the three groups. Of these, the DCF variable according to some authors (Harke) is a criterion for determining age. The three cranial variables with discriminant value refer to the occipital area, by the size of the occipital condyles, the height of the neurocranium and the length of the skull to the intersection of the frontal, parietal and occipital bones, whose sutures, according to some authors [16], disappear with age.

5. Conclusions

Applied on a segment of 66 specimens of adult deer from the area of the Curvature Carpathians and consisting of specimens from 8 mountain ranges, this study reveals some interesting aspects regarding the relationships established between the cranial variables and those of the trophy.

The descriptive analysis of these variables highlighted the degree of variability of this sample, a starting point in their comparison with other populations. The analysis of correlations and regressions highlighted the links established between these variables, generating through simple and multiple regression mathematical expressions that reveal these links.

The discriminant analysis performed between the three age groups highlighted the variables with discriminant value for both the cranial and trophy variables, the correct classification of the discriminant score being 85.96% per total experiment.

In order to create a clearer picture of these aspects, it is necessary to study more data, especially for the category of young specimens.

Acknowledgement

We would like to thank our colleagues from hunting associations and trophy owners for permission to measure and analyze the samples. We are very thankful to reviewers for their valuable comments on an earlier version of the manuscript.

References

1. Almăşan H., Ilie E., Scărlătescu G.E., 1977. Date somatometrice la cerbul comun (*Cervus elaphus hippelaphus* Erxl.) din România. In: Analele ICAS, vol. 35, pp. 17-28.
2. Bradvarovic J., 2017. Jeleni (*Cervus elaphus* L., 1758) Dunskovo – Karpatskog Basena – Udruzejne za

zastitu Dunava i Save Republike Srbije.

3. Burbaite L., Csany S., 2010. Red deer population and harvest changes in Europe. In: Acta Zoologica Lituanica, vol. 20(4), pp. 179-188.
4. Cegielski M., Calkosinski I., Dziegiel P. et al., 2006. Search for stem cells in the growing antler stag (*Cervus elaphus*). In: Bulletin – Veterinary Institute in Pulawy, vol. 50(2), pp. 247-521.
5. Cotta V., Bodea M., Micu I., 2001. Vânatul şi vânătoarea în România. Editura Ceres, Bucharest, Romania.
6. Croitor R., Cojocaru I., 2015. An antlered skull of a subfossil red deer - *Cervus elaphus* L., 1758 (Mammalia, Cervidae) from Eastern Romania. In: Acta Zoologica Bulgarica, vol. 68(3), pp. 407-414.
7. Danilkin A.A., 1999. Deer (Cervidae). In: Series: Mammals of Russia and adjacent regions. Geos Publishing House, Moscow, Russia.
8. Feulner P.G., Bielfeldt W., Zachos F.E. et al., 2004. Mitochondrial DNA and microsatellite analyses of the genetic status of the presumed subspecies *Cervus elaphus montanus* (Carpathian red deer). In: Heredity, vol. 93(3), pp. 299-306.
9. Geist V., 1998. Deer of the world. Their evolution, behavior and ecology. First edition. Stackpole Books, Mechanicsburg, Pennsylvania.
10. Janiszewski P., Gugołek A., Hanzal V. et al., 2011. Variability of the carcass weight of the red deer (*Cervus elaphus* L.) in Poland. In: Polish Journal of Natural Science, vol. 26(2), pp. 99-110.
11. Janiszewski P., Kolasa S., 2006. Zoometric characteristics of red deer (*Cervus elaphus* L.) stags from Northern Poland. In: Baltic Forestry, vol. 12(1), pp. 122-127.
12. Loy A., 2007. Morphometrics and theriology: Homage to Marco Corti. In: Hystrix Italian Journal of Mammalogy (n.s.), vol. 18(2), pp. 115-136.
13. Markov G., 2014. Morphometric variations in the skull of the red deer (*Cervus elaphus* L.) in Bulgaria. In: Acta Zoologica Bulgarica, vol. 66(4), pp. 453-460.
14. Mattioli S., Ferretti F., 2014. Morphometric charcaterization of Mesola red deer *Cervus elaphus italicus* (Mammalia, Cervidae). In: Italian Journal of Zoology, vol. 81(1), pp. 144-154.
15. Merino M.L., Milne N., Vizcaíno S.F., 2005. A cranial morphometric study of deer (Mammalia, Cervidae) from Argentina using three-dimensional landmarks. In: Acta Theriologica, vol. 50(1), pp. 91-108.
16. Mystkowska T.E., 1966. Morphological variability of the skull and body weight of the red deer. In: Acta Theriologica, vol. XI, Bialowieza, no. 5, pp. 129-194.
17. Pélabon C., van Breukelen L., 1998. Asymmetry in antler size in roe deer (*Capreolus capreolus*): an index of individual and population conditions. In: Oecologia, vol. 116, pp. 1-8.
18. Roșu A., 1980. Geografia fizică a României. Editura Didactică și Pedagogică, Bucharest, Romania.
19. Salmeron D.M., 2014. Three-dimensinal study of the Iberian red deer antler (*Cervus elaphus hispanicus*): Application of geometric morphometrics techniques and other

methodologies. PhD Thesis. Barcelona, Spain.

20. Șelaru N., 2000. Trofee de vânat. Editura A.R.E.D.,Bucharest, Romania.
21. Tucak Z., 1997. Morphometrical characteristics of red deer (*Cervus elaphus* L.) from the Donau region in Baranja. In: Zeitschrift für Jagdwissenschaft, vol. 43, pp. 141-153.
22. *** *Cervus elaphus subsp. carpatichus*, Tatarinov, 1956. In: GBIF Secretariat (2021). GBIF Backnone Taxonomy Chacklist dataset. Available at: https://doi.org/10.15468/39omei. Accessed on 25 May, 2021.
23. *** *Cervus montanus* Botezat, 1903. In: GBIF Secretariat (2021). GBIF Backnone Taxonomy Chacklist dataset. Available at: https://doi.org/10.15468/39omei. Accessed on 25 May, 2021.
24. *** *Cervus pannoniensis*, Banwell, 1997. In: GBIF Secretariat (2021). GBIF Backnone Taxonomy Chacklist dataset. Available at: https://doi.org/10.15468/39omei. Accessed on 25 May, 2021.
25. *** *Cervus pannoniensis,* Groves and Grubb 2011. Available at: http://www.ultimateungulate.com/NewTaxonomy.html. Accessed on 25 May, 2021.
26. *** Statistix 8.1 Software
27. *** www.mmap.ro accessed on 20 December, 2020.
28. www.tes.com, accessed on 20 December, 2020.

Appendix list

A1. Trophy variables

Fig. 1. *The scheme for measuring the trophy variables (original)*

A2. Cranial variables

Fig. 2. *Craniometric variables of the dorsal face (original)*

Fig. 3. *Craniometric variables of the lateral face, height of the viscerocranium (N-St) and neurocranium (Sph-Br) (original)*

Fig. 4. *Craniometric variables of the ventral face (original)*

Fig. 5. *Craniometric variables of the occipital face (original)*

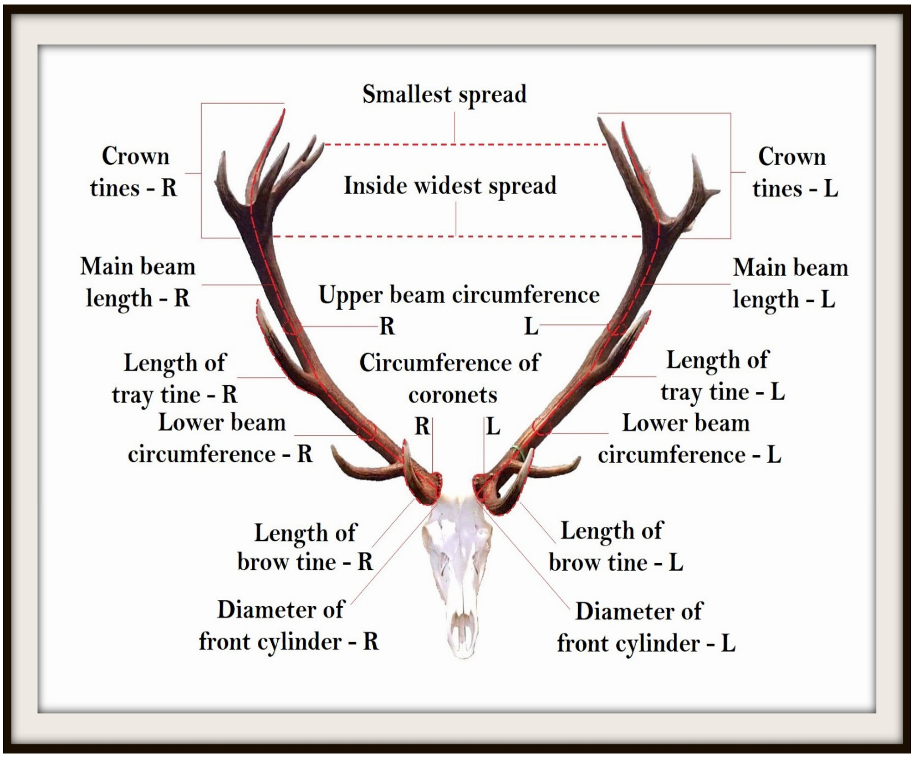


Fig. 1. *The scheme for measuring the trophy variables (original)*

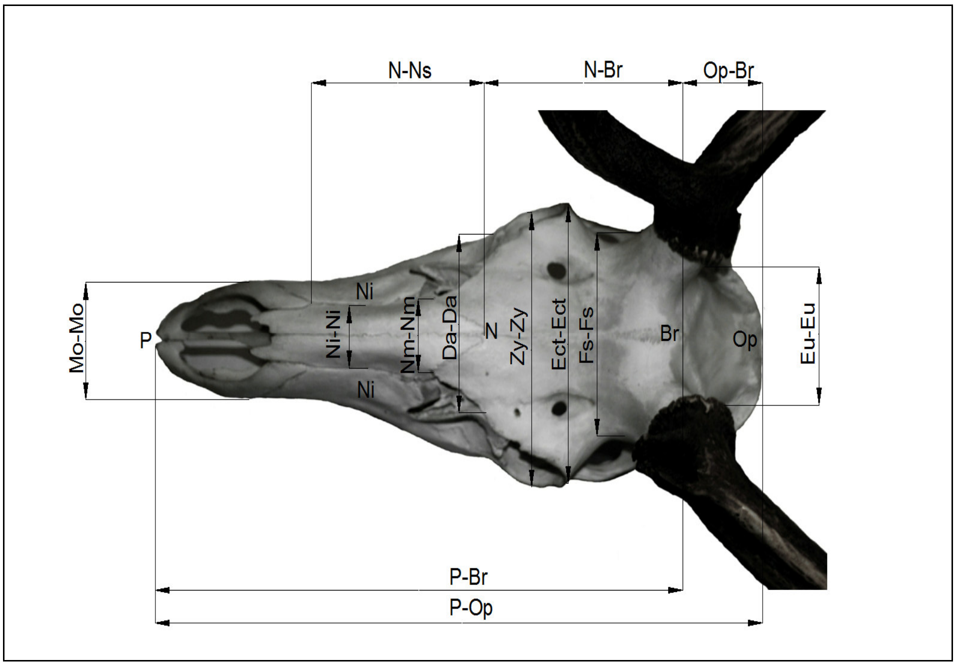


Fig. 2. *Craniometric variables of the dorsal face (original)*

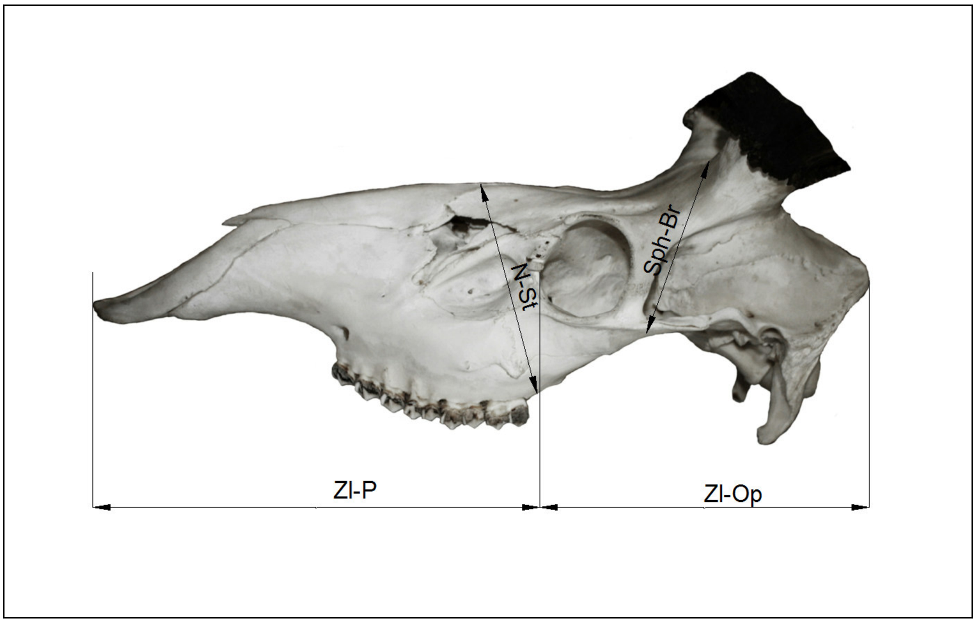


Fig. 3. *Craniometric variables of the lateral face, height of the viscerocranium (N-St) and neurocranium (Sph-Br) (original)*

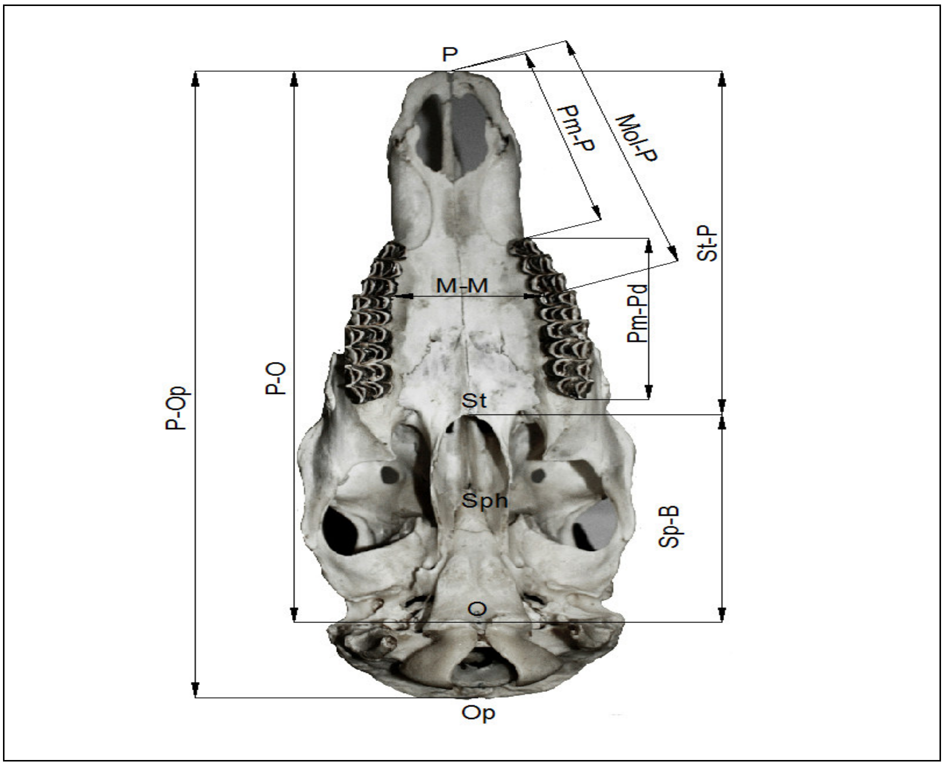


Fig. 4. *Craniometric variables of the ventral face (original)*

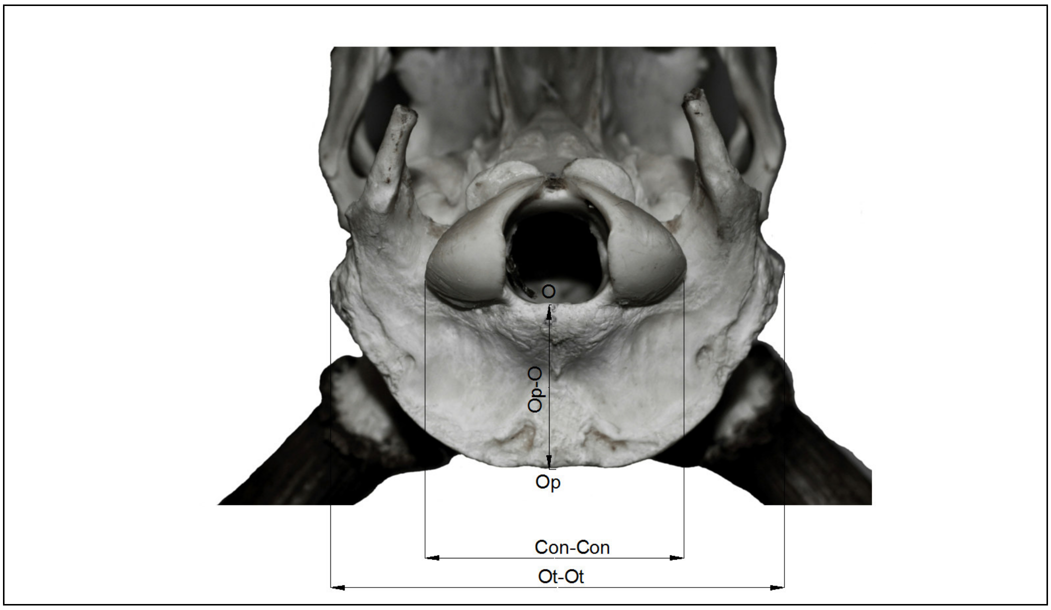


Fig. 5. *Craniometric variables of the occipital face (original)*

AUTHORS INDEX