



ROMANIAN
INVENTORS
FORUM

ISSN 2067-533X

INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

Volume 11 Issue 4 October/December 2020



"Saint Mark" Wood Painted Icon, Private Collection

15 December 2020

Editor in Chief:
Prof. Ion SANDU PhD

OPEN ACCESS
www.ijcs.uaic.ro

DIRECT MENU ▼

International Journal of Conservation Science (<https://ijcs.ro/>)

THE JOURNAL ([HTTPS://IJCS.RO/ABOUT-JOURNAL/](https://ijcs.ro/about-journal/))

EDITORIAL BOARD ([HTTPS://IJCS.RO/EDITORIAL-BOARD/](https://ijcs.ro/editorial-board/))

SUBMISSION ([HTTPS://IJCS.RO/SUBMIT-YOUR-ARTICLE/](https://ijcs.ro/submit-your-article/))

ARCHIVE ([HTTPS://IJCS.RO/ARCHIVE/](https://ijcs.ro/archive/))

ETHICS ([HTTPS://IJCS.RO/ETHICS-RIGHTS/](https://ijcs.ro/ethics-rights/))

Editorial Board

INTERNATIONAL JOURNAL OF CONSERVATION

SCIENCE

([HTTPS://IJCS.RO](https://ijcs.ro/))

> EDITORIAL BOARD

Romanian Inventors

Forum

Secretary:

Dr. Maria T. DOMENECH-

Iasi, Romania**Editor in Chief:**

Prof.dr. Ion SANDU –
Al.I.Cuza University of Iasi (RO)

Senior Editors:

Prof.dr. Mihai BRANZILA
– Al.I.Cuza University of Iasi
(RO)

Dr. Vasile COTIUGA –
Al.I.Cuza University of Iasi (RO)

Dr. Victor VELTER –
UEFISCDI Bucharest (RO)

Publishing Editor:

Dr.Eng. Andrei Victor
SANDU – Gh.Asachi Technical
University of Iasi (RO)

Dr. Roxana Gabriela
CURCA – Al.I.Cuza University
of Iasi (RO)

Editorial Board**CARBO**

Dr. Mohammad A. El-
GOHARY

Dr. Mikiko HAYASHI
Drd. Ioan Cristinel

NEGRU

Dr. Vasile PELIN
Dr. Ioan Gabriel SANDU
Dr. Viorica VASILACHE

Proof Readers:

Stefan CALINIUC

For authors:

-
- Instructions for authors
(<https://ijcs.ro/instructions-for-authors/>)
 - Ethics (<https://ijcs.ro/ethics-rights/>)
 - PDF Ethics & Instructions
(<https://IJCS.ro/IJCS.pdf>)
 - Submission
(<https://ijcs.ro/submit-your-article/>)
 - Manuscript Template
(https://IJCS.ro/IJCS_TEMPLATE.doc)
 - Indexing
(<https://ijcs.ro/indexing/>)
 - Contact the Journal
(<https://ijcs.ro/contact/>)

Explore

-
- Current Issue
(<https://ijcs.ro/current->

Liviu APOSTOL – Alexandru Ioan

Cuza University of Iasi (RO)

Peter BRIMBLECOMBE –

University of Hong Kong (HK)

M.Mustafa Al Bakri ABDULLAH

– Universiti Malaysia Perlis (MY)

Calin BACIU – Babes-Bolyai

University (RO)

Marian BORDEI – Dunarea de Jos

University of Galati (RO)

Petru BUDRUGEAC – ICPE-CA

Bucuresti (RO)

Diana BULGARU-ILIESCU –

Institute of Forensic Medicine, Iasi(RO)

Ana Teresa CALDEIRA –

Universidade de Evora (PT)

Mihaela CAMPEAN – Transilvania

University of Brasov (RO)

Antonio Estevao CANDEIAS –

Universidade de Evora (PT)

Antonio Joao CRUZ – Instituto

Politecnico de Tomar (PT)

Corina IONESCU – Babes-Bolyai

University of Cluj-Napoca (RO)

Takeshi ISHIZAKI – University of

Tokyo (JP)

Kinga KOSTRAKIEWICZ-

GIERALT – University of Physical

Education in Krakow (PL)

Innocent K. KOUAME – Université

Nangui Abrogoua, Abidjan (CIV)

Mauro Francesco LA RUSSA –

University of Calabria (IT)

Ioannis LIRITZIS – University of the

Aegean (GR)

Tudor LUPASCU – Chemistry

Institute of Science Academy of Moldova,

Chisinau (MD)

Nicola MACCHIONI – IVALSA,

Firenze (IT)

Constantin MARUTOIU – Babes-

Bolyai University of Cluj-Napoca (RO)

Andras MORGOS – National

Museum of Budapest (HU)

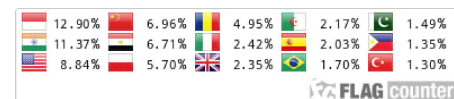
issue/)

- **Archive**

(<https://ijcs.ro/archive/>)

News & Events

(<https://ijcs.ro/news/>)



(<https://info.flagcounter.com/0y8Q>)

Dan CASCAVAL – Gheorghe Asachi Technical University Iasi (RO)	Valentin NEDEFF – Vasile Alexandri University of Bacau (RO)
Maria Perla COLOMBINI – Universita di Pisa (IT)	Marianne ODLYHA – University of London (UK)
Eduard COROPCEANU – Tiraspol University (MD)	Ioanna PAPAYIANNI – University of Thessaloniki(GR)
Gyorgy DEAK – N.I.R.D. for Environmental Protection (RO)	Daniela PINNA – University of Bologna (IT)
Antonio DOMENECH-CARBO – University of Valencia (ES)	Paraskevi POULI – Institute of Electronic Structure and Laser, Heraklion (GR)
Gabi DROCHIOIU – Alexandru Ioan Cuza University of Iasi (RO)	Marielle RICHON – UNESCO, Paris (FR)
Gheorghe DUCA – State University of Chisinau (MD)	Erkan SAHINKAYA – Medeniyet University of Istanbul (TR)
Octavian G. DULIU – University of Bucharest (RO)	Irina Crina Anca SANDU – Munch Museet, Oslo (NO)
Paola FERMO – Universita degli Studi di Milano (IT)	Manfred SCHREINER – Academy of Fine Arts Vienna, Vienna (A)
Maria GAVRILESCU – Gheorghe Asachi Technical University Iasi (RO)	Piero TIANO – CNR ICVBC, Firenze (IT)
Lucian P. GEORGESCU – Dunarea de Jos University of Galati (RO)	Akos TOROK – University of

Technology and Economics of Budapest

(HU)

Cristina Maria TIMAR –

Transilvania University of Brasov (RO)

Vasile VANTU – The University of

Agricultural Sciences and Veterinary

Medicine, Iasi (RO)

Reviewers Board Supervisors

Denyo ALIPIEV – Sofia

(BG)

Cecilia ARSENE – Iasi

(RO)

Nicolae BILBA – Iasi (RO)

Costica BEJINARIU – Iasi

(RO)

Luminita BEJENARIU –

Iasi (RO)

Dorica BOTAU –

Timisoara (RO)

Oana Adriana CUZMAN

– Firenze (IT)

Lacramioara IVANESCU –

Iasi (RO)

Francesca Caterina IZZO

– Venezia (IT)

Innocent Kouassi

KOUAME – Abidjan (CI)

Kamel EARAR – Ramallah

(PS)

Constantin LUCA – Iasi

(RO)

Liliana Rozemarie

MANEA – Iasi (RO)

Mihai COSTICA – Iasi (RO)	Otilia MIRCEA – Roman (RO)
Ana DONIGA – Galati (RO)	Mircea NICOARA – Iasi (RO)
Toni Cristian DUMITRIU – Iasi (RO)	Ionut Cristi NICU – Oslo (NO)
Amin A. EL-MELIGI – Cairo (EG)	Romeo Iulian OLARIU – Iasi (RO)
Anca EMANDI – Bucuresti (RO)	Vasile SIRBU – Iasi (RO)
Walter A. FRANKE – Frankfurt (DE)	Joseph Marie SIELIECHI – Ngaoundere (CM)
Carmen GACHE – Iasi (RO)	Hiren B. SONI – Gujarat (IN)
Milene GIL DUARTE CASAL – Lisboa (PT)	Manuela VAGNINI – Spoleto (IT)
Lidia GURAU – Brasov (RO)	Violeta VASILACHE – Suceava (RO)
Lucian GORGAN – Iasi (RO)	Petrica VIZUREANU – Iasi (RO)
	Shuya WEI – Viena (A)
	Olivier WELLER – Paris (FR)

EDITORIAL OFFICE

Editor-in-Chief: Prof.dr. Ion SANDU

Romanian Inventors Forum

Str. Sf. P. Movila 3, L11, III/3

Iasi – ROMANIA

ijcs_editor@yahoo.com

(mailto:ijcs_editor@yahoo.com) & office@ijcs.ro

(mailto:office@ijcs.ro)

www.ijcs.ro (https://ijcs.ro)

ISSN: 2067-533X & eISSN: 2067-8223

ISSUE COVER



(<http://ijcs.ro/img/cover132.jpg>)

PUBLICATION MODEL



This work is licensed under a Creative Commons Attribution

- Non Commercial - No Derivatives 4.0 International License.



(<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

© SAV 2020. All Rights Reserved.

Table of contents: **Volume 11, Issue 4, 2020**

S. Martins, C. Salvador, A. Candeias, A.T. Caldeira, A. Pereira

Methodology for the Synthesis of Chitosan Derivatives to be Applied in Cultural Heritage

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-62_Martins.pdf)] pp. 867-874

L. Mohammedi, A. Abdessemed Foufa, M. Cheikh Zouaoui

Analyse and Repair of Stone Masonry Building in Mediterranean Areas: Case of Pouillon's Housing Estates in Algiers, Algeria

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-63_Mohammedi.pdf)] pp. 875-882

M. Mohie, G.M. Sultan

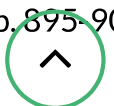
Detachment and Transferring of Old Wood Painted Icon to New Suggested Alternative Support

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-64_Mohie.pdf)] pp. 883-894

N. Aly, A. Hamed

The Impact of Salt Crystallization on the Building Stones of Al-Azhar Mosque from Historic Cairo – Egypt

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-65_Aly.pdf)] pp. 895-904



M. Lisinska-Kusnierz, M. Krupa, K. Paprzyca, J. Sygula-Cholewinska, K. Kusnierz, O. Ivashko
Deterioration of Wood by Microorganisms in a Historical Building on the Example of a Historical
Health Resort Villa

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-66_Lisinska-Kusnierz.pdf)] pp. 905-916

Y. Abu Alhassan, M. Al-Naddaf, R. Azzam
Evaluation of the Efficiency of Sodium Ferrocyanide as a Crystallization Inhibitor in Monumental
Sandstones in Petra – Jordan

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-67_Alhassan.pdf)] pp. 917-930

D.B. Wiyanto, N. Harahab, Rudianto, A. Sartimbul
Cultural Heritage Conservation of “The United State Army Transport (USAT) Liberty” Shipwreck
Site as a Sustainable Scuba Diving Ecotourism

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-68_Wiyanto.pdf)] pp. 931-944

T.V. Panyok
Historical-Cultural and Lighting Context of Artistic Education in Ukraine in the Beginning of the
20th Century

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-69_Panyok.pdf)] pp. 945-952

Y. Ivashko, A. Dmytrenko, K. Paprzyca, M. Krupa, T. Kozłowski
Problems of Historical Cities Heritage Preservation: Chernihiv Art Nouveau Buildings

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-70_Ivashko.pdf)] pp. 953-964

M. Malusare, M.R. Singh
Pewter Filled Seashell Coins from Central India (500 BC – 11th CE) – Surface Morphology and
Micro-Structure

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-71_Malusare.pdf)] pp. 965-978

C. Balocco, S. Vestrucci
An Experimental Study of Museum Showcases in Florence under Real Operating Conditions

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-72_Balocco.pdf)] pp. 979-996



K. Bouzetine, M. Hamiane, A. Brahim, M. Belaidi

Alteration of Sidi Ghanem Mosque Limestone. Influence of the Lithological Nature and the Environmental Conditions

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-73_Bouzetine.pdf)] pp. 997-1004

C.A. Kwiatkowski, E. Harasim, L. Pawlowski

Can Catch Crops be an Important Factor in Carbon Dioxide Sequestration?

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-74_Kwiatkowski.pdf)] pp. 1005-1018

M.M. Cazacu, V. Pelin, I. Radinschi, I. Sandu, V. Ciocan, I.G. Sandu, S. Gurlui

Effects of Meteorological Factors on the Hydrophobization of Specific Calcareous Geomaterials from Repedea – Iasi Area, Under the Urban Ambient Air Exposure

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-75_Cazacu.pdf)] pp. 1019-1030

A.M. Abdelmoniem, N. Mahmoud, W.S. Mohamed

Archaeometric Study of Black Resin of a Late Period Coffin By Gas Chromatography-Mass Spectrometry

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-76_Abdelmoniem.pdf)] pp. 1031-1040

H. Hegui

Hydrochemical Faciers of Mineral Water and Classification Standards in Algeria

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-77_Hegui.pdf)] pp. 1041-1050

G. Mihai, L. Dinca

In Situ Conservation of Forest Genetic Resources From the Southern Carpathians

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-78_Mihai.pdf)] pp. 1051-1058

D. Wahyudi, N.I. Adnin, L. Hapsari

Intraspecific Variation of Thirteen Pisang Ambon Cultivars (*Musa Acuminata* cv. Aaa) from East Java and Central Java (Indonesia) Based on Random Amplified Polymorphic DNA (RAPD) Marker

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-79_Wahyudi.pdf)] pp. 1059-1070

C.T. Balaceanu, D.L. Zaharia, M. Gruiescu, M. Constantinescu, G. Deak

Sustainable Measures in Environmental Protection Through Green Products



[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-80_Balaceanu.pdf)] pp. 1071-1082

D. Sulistiawati, K. Mansyur, A.E.P.N. Serdiati, A. Laapo, M.N. Ali, M. Khairil, W.P.S. Hamzens
Management Strategies of Coral Reefs Fisheries in Banggai Laut Archipelago, Central Sulawesi,
Indonesia

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-81_Sulistiawati.pdf)] pp. 1083-1092

R. Shaheen, M. Fouad, O. Saqr, S. Reda, A. Labeeb
Assessment of the Photo-Chemical Degradation of Silver Gelatin Photograph Print-Out

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-82_Shaheen.pdf)] pp. 1093-1102

A. Nurhayati, I. Aisah, A.K. Supriatna
Community-Based Environmental Education In Coastal Regions and Its Role in the Conservation of
Fisheries Resources in Indonesia

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-83_Nurhayati.pdf)] pp. 1103-1114

A.R. Jalil, A. Malik, N. Nurdin, A. Saru, I. Yunus
Assessment of Seawater Level, Inundation Duration and Substrate Elevation for Mangrove
Rehabilitation Program in the Spermonde Archipelago South Sulawesi Indonesia

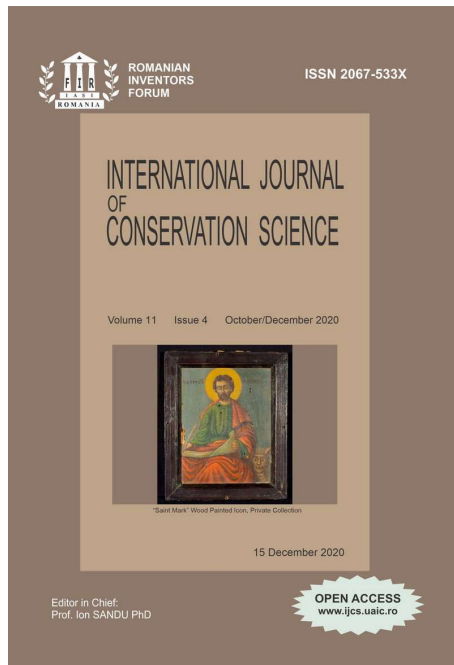
[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-84_Jalil.pdf)] pp. 1115-1126

Y.T.N. Dewi, J. Kwik, Y.T. Sunarimahingsih, B.T. Susanti
Preservation as Reconciliation: The Value of Raising Awareness on Cultural Property in Post-
Conflict Ambon

[**Full Article – PDF** (https://ijcs.ro/public/IJCS-20-85_Dewi.pdf)] pp. 1127-1134

Publication date: **December 15, 2020**





(<https://ijcs.ro/img/cover114.jpg>)

•

Archive

- Current Issue (<http://ijcs.ro/current-issue/>)
 - Volume 13 - 2022 (<http://ijcs.ro/volume-13-2022/>)
 - Volume 12 - 2021 (<http://ijcs.ro/volume-12-2021/>)
 - Volume 11 - 2020 (<http://ijcs.ro/volume-11-2020/>)
 - Volume 10 - 2019 (http://ijcs.ro/volume_10.html)
 - Volume 9 - 2018 (http://ijcs.ro/volume_9.html)
 - Volume 8 - 2017 (http://ijcs.ro/volume_8.html)
 - Volume 7 - 2016 (http://ijcs.ro/volume_7.html)
 - Volume 6 - 2015 (http://ijcs.ro/volume_6.html)
 - Volume 5 - 2014 (http://ijcs.ro/volume_5.html)
 - Volume 4 - 2013 (http://ijcs.ro/volume_4.html)
 - Volume 3 - 2012 (http://ijcs.ro/volume_3.html)
 - Volume 2 - 2011 (http://ijcs.ro/volume_2.html)
 - Volume 1 - 2010 (http://ijcs.ro/volume_1.html)
-
- Indexing (<http://ijcs.ro/indexing/>)
 - Ethics and Rights (<http://ijcs.ro/ethics-rights/>)



- Instructions For authors (<http://ijcs.ro/instructions-for-authors/>)
- Submission (<http://ijcs.ro/submit-your-article/>)
 - Manuscript Template (https://ijcs.ro/IJCS_TEMPLATE.doc)

EDITORIAL OFFICE

Editor-in-Chief: Prof.dr. Ion SANDU

Romanian Inventors Forum

Str. Sf. P. Movila 3, L11, III/3

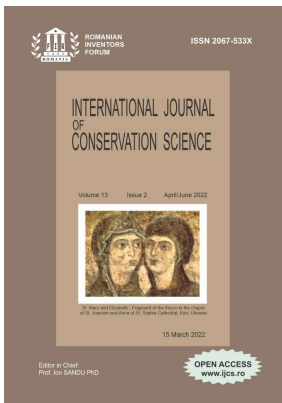
Iasi – ROMANIA

ijcs_editor@yahoo.com (mailto:ijcs_editor@yahoo.com) & office@ijcs.ro (<mailto:office@ijcs.ro>)

www.ijcs.ro (<https://ijcs.ro>)

ISSN: 2067-533X & eISSN: 2067-8223

ISSUE COVER



(<http://ijcs.ro/img/cover132.jpg>)

PUBLICATION MODEL



This work is licensed under a Creative Commons Attribution - Non Commercial - No Derivatives 4.0 International License.



(<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

© SAV 2020. All Rights Reserved.



ASSESSMENT OF SEAWATER LEVEL, INUNDATION DURATION AND SUBSTRATE ELEVATION FOR MANGROVE REHABILITATION PROGRAM IN THE SPERMONDE ARCHIPELAGO SOUTH SULAWESI INDONESIA

Abd. Rasyid JALIL^{1,*}, Abdul MALIK², Nurjannah NURDIN¹,
Amran SARU¹, Ibrahim YUNUS³

¹ Department of Marine Science, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, Jl. Perintis
Kemerdekaan Km. 10, Makassar, 90245 South Sulawesi, Indonesia.

² Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar, Jl. Malengkeri
Raya, Kampus Parangtambung, Makassar, 90224 South Sulawesi, Indonesia.

³ Lembaga Survei Nypa Indonesia, Jl. Perintis Kemerdekaan Km. 10, Makassar, 90245 South Sulawesi, Indonesia.

Abstract

Assessments of seawater level, substrate elevation, and inundation duration are known to contribute to the success of mangrove rehabilitation programs. However, the majority of such programs have disregarded the need for these assessments. The objectives of this study are to assess seawater level and inundation duration, and subsequently determine suitable substrate elevation ranges for specific mangrove species used at a mangrove rehabilitation program in the Sagara Island of Spermonde Archipelago, South Sulawesi, Indonesia. During field surveys, substrate elevation and seawater levels were measured, and inundation patterns observed for 24 hours. The mangrove species found at each elevation level were identified. To predict seawater levels during 2016, tidal prediction data for the area were obtained from the Hydro-Oceanographic Department (DISHIDROS) of the Indonesian Navy. The seawater inundation frequency varied between once and twice a day, with the highest inundation duration (21-24 hours) at the Mean Lower Low Water Spring (MLLWS) level. The appropriate planting range for most mangrove species, concerning seawater level and seaward to landward substrate elevation, were between Mean Lower Low Water Spring (MLLWS) and Mean Highest High Water Spring (MHHWS) tidal levels.

Keywords: *Mangrove rehabilitation; Hydrological conditions; Substrate elevation; Spermonde Archipelago*

Introduction

Mangrove forests are found in many coastal areas of tropical and subtropical countries situated between 30°N and 30°S latitude [1]. These forests are frequently affected by the tides, adapted to fluctuating salinity regimes, and dominated by trees, shrubs, palms, epiphytes, and ferns [2]. Mangroves provide a wide range of benefits, including protecting coastlines from wave and wind energy, storm, and abrasion, preventing seawater intrusion, carbon sequestration, providing spawning, nursery and feeding and grounds for marine biota, acting as a nutrient source for neighbouring ecosystems, and providing habitat for wildlife such as birds, reptiles and primates. Mangroves also support a number of economic resources and benefits, including forestry products (firewood, charcoal, and housing materials), fisheries products (fish, crabs, shrimps, and molluscs), medicinal products, and ecotourism [3 - 6].

* Corresponding author: abdulrasyid.fayufi@gmail.com

The most recent worldwide extent of mangrove forests was estimated at 16.4 million hectares in 2014 [7], distributed around the coast of 118-124 countries [1]. However, mangroves are mainly concentrated in 15 countries [1] with the largest mangrove forest areas found in Indonesia [1, 3, 8]. Unfortunately, over-exploitation of forest products for commercial purposes and conversion of these forests to other land uses (mainly brackish-water aquaculture ponds) resulted in the deforestation and degradation of 3.6 million hectares between 1980 and 2005 [9].

Many mangrove protection and rehabilitation programs have been implemented by government agencies and NGOs in Indonesia and other Southeast Asia countries in recent decades. However, the drivers of mangrove forest loss have rarely been addressed effectively or eliminated, and most of the mangrove rehabilitation programs have been unsuccessful. One common reason for failure has been a concentration on seedling production and planting, without proper regard to the selection of planting sites to ensure they are appropriate for the establishment and growth of the mangrove species planted, in particular in terms of seawater levels and substrate elevation [10 – 17]. One reason why these parameters are often ignored is that they can be difficult to quantify in practice [16]. In addition, most programs use a monospecific planting approach, or low species diversity [18 – 20], and low survival rates are common [15, 17]. For example, the survival rate of mangroves planted under rehabilitation programs in Aceh after the 2004 Tsunami disaster ranged between 15% and 60% [21]. In the Philippines, the survival rate estimated over an 11 period was only 17% to 32% [11].

Low survival rates have occurred due to failure in site and species selection in programs where these parameters were not considered [11, 12, 17]. In particular, *R.R. Lewis* [22] found that, although mangrove plantation activities are not particularly inexpensive, most mangrove rehabilitation programs were not successful due to ignoring the physiological tolerance of mangroves to tidal inundation. It is increasingly clear that it is extremely important to assess seawater levels, inundation patterns, and substrate elevation before undertaking the rehabilitation of disturbed or degraded mangrove areas. These factors play key roles in controlling natural mangrove establishment and regeneration, forest structure and species distribution patterns, and subsequent long-term stability [16, 23, 24] and hence the success of mangrove rehabilitation programs [13]. As stated by *S. Munandar et al.* [15] and proven at mangrove rehabilitation sites in many countries, such as those reported by [25 – 27], tidal inundation patterns and substrate elevation tend to be the leading factors determining mangrove growth.

The objectives of this study are to assess seawater levels, inundation duration, and subsequently determine substrate elevation ranges suitable for the establishment and growth of several mangrove species at a specific mangrove rehabilitation program site. Sagara Island was selected for this case study. This small island is situated in the Spermonde Archipelago, Indonesia. Like many other small islands in the Archipelago, the mangroves around Sagara Island have been heavily exploited, and many were converted to aquaculture ponds. However, most of these ponds have become degraded due to poor maintenance by the farmers, and in recent years many have been abandoned. There were no previous studies on this site that could support the development of mangrove rehabilitation.

Experimental

Study Area

Sagara Island is located in the inner zone of the Spermonde Archipelago, at approximately 4°42'9" latitude and 119°27'18" longitude, about 47km from Makassar City, the capital of South Sulawesi Province, Indonesia. Administratively, the island forms part of the North Liukang Tupabbiring District in the Pangkep Regency. The land area of Sagara Island is 33.015ha, while the coastal waters around the island extend for approximately 16.6km².

Mangrove forests originally characterized the Island and surrounded by extensive seagrass meadows and coral reefs [28].

Mangroves originally covered 17.209ha, extending all around the coast of Sagara island. The widest mangrove belt, extending up to 160 meters from the shoreline, was on the western coast, and comprised the majority (10.33 ha) of the mangrove forest area [28]. However, since the island was settled, the majority of the mangroves been cleared and converted to aquaculture ponds [28] (Fig. 1). These ponds were mainly used for semi-intensive culture [29]. Over the period 1990-2015, around 10.08ha of mangrove cover was lost due to overharvesting of wood and the development of aquaculture ponds [28].

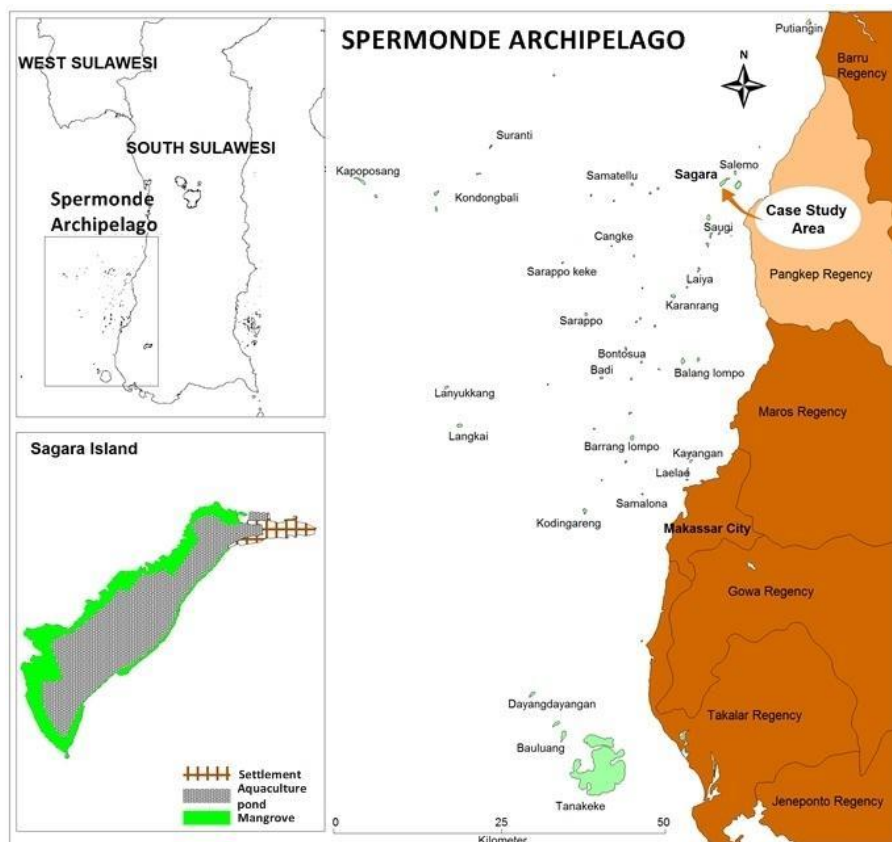


Fig. 1. Sagara Island in the Spermonde Archipelago, Pangkep Regency, South Sulawesi Province, Indonesia

Data Collection

Secondary data was used in this study comprised of tidal height prediction data for 2016. This data was gathered from the Naval Hydro-Oceanographic Department (DISHIDROS) of the Republic of Indonesia.

Primary data were collected on seawater level, substrate elevation, and mangrove species composition. These data were collected for seven days in July 2016. Seawater levels were recorded over 24 hours using a Hobo Water Logger. These data were used to verify the tidal prediction data from DISHIDROS and to predict water levels. These data were also used as a reference for calculating substrate elevations in mangrove areas using an Autolevel device supported by a Global Positioning System (GPS) unit, watch, and scaling poles (Fig. 2).

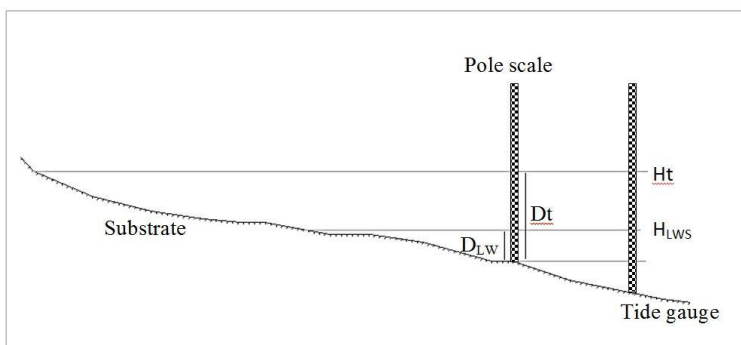


Fig. 2. Measurement of seawater depth relative to mean low water spring tide (LWS) level (adapted from Baharuddin, 2006 [33])

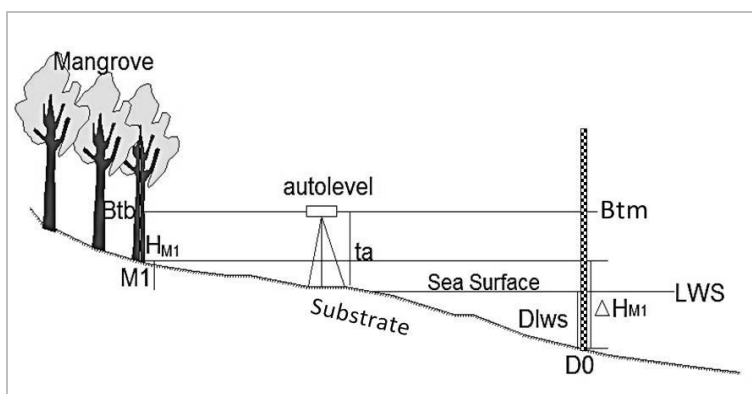


Fig. 3. Measurement of mangrove substrate elevation relative to mean low water spring tide seawater level (LWS) using a reference point (D0) and an Autolevel (adapted from Frick, 1984 [30]; USAID, 2005 [31])

Substrate elevation was measured using two approaches: measurement of the depth water from the surface to the substrate, and using substrate height difference or leveling [30, 31]. The first approach was conducted when mangrove areas were inundated, whereas the second approach was applied when mangroves were not flooded, or at low tide (Fig. 3). The first stage was to measure water depth at one point, flooded with in water connected to the sea, which was marked as a depth reference point. The measurements of substrate height differences were conducted on the outer (non-flooding) edge of the mangrove area, with reference to this depth reference point. The substrate height differences were measured from the seaward edge to the landward boundary of the distribution of each selected mangrove species [31]. Substrate elevation measurements were validated using an Autolevel measuring device, by measuring the depth of the substrate with a scaling pole simultaneously at one mangrove sampling point while still inundated, while the depth was validated by the tidal data measurements. Thus, the depth and elevation data obtained could be related to the mean sea level (MSL). The mangrove species found at each elevation level were recorded and considered as representative of the species present at that elevation.

Data Analysis

Seawater levels were calculated using formulas 1-7 [32, 33]:

$$\text{HAT (Highest Astronomical Tide)} = \text{LAT} + 2(\text{AK}_1 + \text{AO}_1 + \text{AM}_2 + \text{AS}_2) \tag{1}$$

$$\text{MHHWS (Mean Highest High-Water Spring)} = \text{LAT} + 2(\text{AK}_1 + \text{AO}_1) + \text{AM}_2 + \text{AS}_2 \tag{2}$$

$$\text{MHHWN (Mean Highest High-Water Neap)} = \text{LAT} + 2(\text{AK}_1) + \text{AM}_2 + \text{AS}_2 \tag{3}$$

$$\text{MSL (Mean Sea Level)/So} = 90 \text{ cm (adapted from DISHIDROS)} \tag{4}$$

$$\text{MLLWN (Mean Lowest Low Water neap)} = \text{LAT} + 2(\text{AO}_1) + \text{AM}_2 + \text{AS}_2 \tag{5}$$

$$\text{MLLWS (Mean Lowest Low Water Spring)} = \text{LAT} + \text{AM}_2 + \text{AS}_2 \quad (6)$$

$$\text{LAT (Lowest Astronomical Tides)} = \text{MSL} - (\text{AK}_1 + \text{AO}_1 + \text{AM}_2 + \text{AS}_2) \quad (7)$$

where:

- AK₁ : amplitude of lunar diurnal component (K₁);
- AO₁ : amplitude of lunar declinational diurnal component (O₁);
- AM₂ : amplitude of principal lunar semidiurnal component (M₂);
- AS₂ : amplitude of principal solar semi-diurnal component (S₂).

The water depth at the depth reference point was calculated using formula 8 [33]:

$$D_{\text{LWS}} = D_t - (H_t - H_{\text{LWS}}) \quad (8)$$

where:

- D_{LWS} : water depth at low tide (cm);
- D_t : water depth at time t (cm);
- H_t : water height at time t (cm) on the tide gauge;
- H_{LWS} : water height at low water on the tide gauge (cm) (Fig. 2).

Calculation of tidal inundation patterns was based on the length of time between tide that passed through five water level categories (MHHWS, MHHWN, MSL, MLLWN, and MLLWS) and recede per day. The result indicates the mean daily duration of inundation within each group.

Mangrove substrate elevations were calculated using formulas 9-11 [30]:

$$H_{D0} = D_{\text{LWS}} \quad (9)$$

$$\Delta H_{M1} = B_{tm} - B_{tb} \quad (10)$$

$$H_{M1} = H_{D0} + \Delta H_{M1} \quad (11)$$

where:

- H_{D0} : height of D0 (cm);
- D_{LWS} : water depth at low tide (cm);
- ΔH_{M1} : difference in elevation between substrate at point M1 and substrate at point D0;
- H_{M1} : height of substrate M1;
- B_{tm} : horizontal plane for D0;
- B_{tb} : horizontal plane for M1;
- ta : height of the Autolevel (cm) (Fig. 3).

Results and discussion

Composition and distribution of mangrove species

A total of 98 mangrove trees were identified. Eleven mangrove species were recorded: *Rhizophora stylosa*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Sonneratia alba*, *Sonneratia caoselaris*, *Avicennia marina*, *Lumnitzera racemosa*, *Scyphiphora hydrophyllacea*, and *Excoecaria agallocha*. Nine species were found along the west coast, seven along the east coast, and five each along the north and south coasts (Table 1). *Rhizophora stylosa* was the most dominant species, followed by *Rhizophora apiculata* and *Sonneratia alba* (Table 1).

Tidal characteristics: seawater levels and inundation patterns

Tidal characteristics contribute to the duration of seawater inundation and thus affect the mangrove species distribution at each elevation in the tidal zone [17]. The tidal analysis showed that the diurnal tide component harmonic constants (K1 and O1) had a greater influence than the semidiurnal tide components (S2 and M2) (Table 2).

The Formzahl number [34] of 1.733 indicates that the prevailing tidal regime at the study site is mixed diurnal (on some days the tidal cycle occurs only once, while on most days there

are two tidal cycles, often with significantly different amplitudes). The seawater level varied between 0 and 164cm relative to LAT, and between -82 and 82cm relative to MSL. The maximum tidal range was 164cm, with a mean neap tidal range of 24cm and a mean spring tidal range of 104cm (Table 3).

Table 1. Mangrove area extent, density, and species

Site	Mangrove area (Ha)	Mangrove belt width (m)	Mangrove species											Number of species
			<i>Rs</i>	<i>Ra</i>	<i>Rm</i>	<i>Bg</i>	<i>Ct</i>	<i>Sa</i>	<i>Sc</i>	<i>Am</i>	<i>Lr</i>	<i>Sch</i>	<i>Ea</i>	
North	1.732	27 - 80	+	+	-	-	-	+	-	-	+	+	-	5
East	1.285	10 - 14	+	+	+	-	-	+	-	-	+	+	+	7
South	3.862	18 - 91	+	+	-	+	-	+	+	-	-	-	-	5
West	10.33	23 - 160	+	+	-	+	+	+	+	+	+	-	+	9
Sub-total			28	22	2	9	2	18	4	2	6	2	3	
Total	17.209							98						

+ Present, - not present

Rs (*Rhizophora stylosa*), *Ra* (*Rhizophora apiculata*), *Rm* (*Rhizophora mucronata*), *Bg* (*Bruguiera gymnorrhiza*), *Ct* (*Ceriops tagal*), *Sa* (*Sonneratia alba*), *Sc* (*Sonneratia caoselaris*), *Am* (*Avicennia marina*), *Lr* (*Lumnitzera racemosa*), *Sch* (*Scyphiphora hydrophyllacea*), and *Ea* (*Excoecaria agallocha*).

Table 2. Tidal harmonic constants for Sagara Island and the surrounding area

	So	M2	S2	N2	K1	O1	M4	MS4	K2	P1
A cm	90	13	17	5	32	20	0	1	5	10
g°		108	216	226	295	265	0	328	216	295

Table 3. Seawater levels around Sagara Island and nearby

Water level types	High water level above LAT (cm)	High water level relative to MSL (cm)	Average tidal range Neap tides (cm)	Average tidal range Spring tides (cm)	Maximum tidal range (cm)
HAT	164	82			
MHHWS	134	52			
MHHWN	94	12			
MSL	82	0	24	104	164
MLLWN	70	-12			
MLLWS	30	-52			
LAT	0	-82			

HAT: Highest Astronomical Tide; MHHWS: Mean Higher High Water Springs; MHHWN: Mean Higher High Water Neaps; MSL: Mean Sea Level; MLLWN: Mean Lower Low Water Neaps; MLLWS: Mean Lower Low Water Springs; LAT: Lowest Astronomical Tide.

Based on the mixed tidal regime, seawater inundation frequency varied between once and twice a day. The longest inundation duration (21-24 hours) occurred at the Mean Lower Low Water Springs (MLLWS) level, with a mangrove substrate elevation of -50cm relative to MSL (Fig. 4). The distribution of each mangrove species differed with respect to seawater inundation. *Rhizophora* spp. and *Sonneratia* sp. had the highest tolerance to the seawater inundation (between 0 and 24 hours) [35], followed by *Bruguiera gymnorrhiza* and *Lumnitzera racemosa* (between 0 and 21 hours) (Fig. 4).

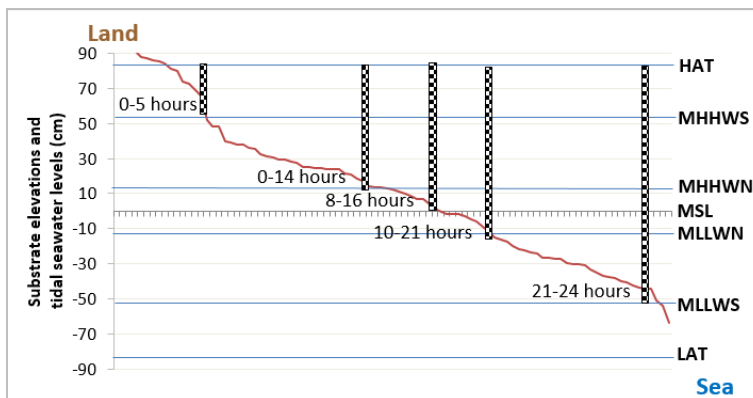


Fig. 4. Duration of daily inundation at different tidal seawater levels and mangrove substrate elevations

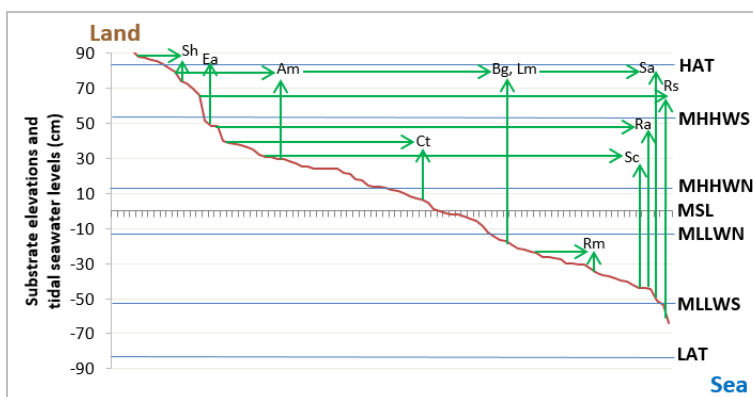


Fig. 5. Mangrove species distribution is relative to substrate elevation and water level. Vertical and horizontal arrows indicate the range of each species. *Rs* (*Rhizophora stylosa*), *Ra* (*Rhizophora apiculata*), *Rm* (*Rhizophora mucronata*), *Bg* (*Bruguiera gymnorrhiza*), *Ct* (*Ceriops tagal*), *Sa* (*Sonneratia alba*), *Sc* (*Sonneratia caseolaris*), *Am* (*Avicennia marina*), *Lr* (*Lumnitzera racemosa*), *Sch* (*Scyphiphora hydrophyllacea*) and *Ea* (*Excoecaria agallocha*)

Mangrove substrate elevation

Substrate elevation ranges of the various mangrove species in relation to seawater levels are shown in figure 5. The greatest expanse of the dry substrate was exposed at the lowest astronomical low tide (LAT), with flood tides rising slowly to the highest level (HAT). The width of the intertidal area and the swiftness of the water flows depend on substrate elevation [36]. Thus, substrate elevations above the HAT (> 90 cm) were no longer regularly flooded with seawater due to tidal cycles. In the study area, the majority of the mangrove species were growing in the zone between the MLLWS and MHHWS. This is different from the coast of Sumatra, where most mangroves species still grow above the average water level [10]. *Rhizophora stylosa* was the most abundant species in this area, followed by *Rhizophora apiculata* and *Sonneratia alba* (Fig. 4, Table 1). Although the majority of specimens of these species were found between the MLLWS and MHHWS (between -50 and 50cm relative to MSL), two *Rhizophora stylosa* trees were found below the MLLWS and one above the MHHWS. Other mangrove species found between these substrate elevations included *Rhizophora apiculata*, *Rhizophora mucronata*, *Sonneratia alba*, and *Sonneratia caesolaris*. The

root systems of these species enable them to be highly tolerant of seawater salinity, and the suitable substrate type (sandy mud) was also most likely a factor promoting their survival in this elevation range [37].

The two mangrove genera *Sonneratia* and *Rhizophora* were frequently found growing adjacent to one another on the sandy mud intertidal substrates. The cone roots of *Sonneratia* sp. rise from the dense flat root system spreading horizontally away from the trunk; they can trap the propagules of *Rhizophora* spp. which are swept away or fall from the mature trees and become stuck in gaps between *Sonneratia* sp. roots, and thus these species can survive and grow together. However, two trees, one *Sonneratia alba* and one *Avicennia marina*, were found growing at the HAT and surviving on sandy substrate. Substrate distribution at this elevation is associated with sediment transport mechanisms [38]. Sandy substrates carried by the longshore currents are deposited when they meet a barrier. The root systems characteristic of *Sonneratia Alba* with their horizontal distribution can bind this sediment type [39 - 41].

At higher substrate elevations (near the MLLWN), the mangrove species found were *Bruguiera gymnorrhiza* and *Lumnitzera racemosa*. *Bruguiera gymnorrhiza* was commonly found in the mid intertidal zone, in the middle of the mangrove ecosystem range, but its range also tended to extend to the boundary with dry land or the highest limit of the intertidal zone [2, 42, 43]. This species has lower knee roots with typical pneumatophores [37]. According to [44], the knee root is a modification of cable roots. The horizontal roots, which mostly grow just below the soil surface, periodically grow vertically upwards then immediately loop downwards to resemble a bent knee. In the meanwhile, in *Lumnitzera racemosa* pneumatophores are normally absent [37], demonstrating that this species tends to tolerate restricted periodic seawater inundation. This species is often found in the upper tidal zone from mid to high intertidal zone [45], but has also been recorded along the sandy beaches [46].

In addition, four mangrove species were found growing above the MSL, including *Ceriops tagal*, *Avicennia Marina*, *Excoecaria agallocha* and *Scyphiphora hidroyllacea*. The distributions of these species are controlled by substrate elevation relative to the MSL [46]. However, the number of individuals of each of these species was low (around 2 - 3 individuals). The presence of *Ceriops tagal* and *Avicennia Marina* at this elevation is related to the relatively low tidal range, short period of inundation and sandy mud sediment, all of which are characteristics suitable for the growth of these species. According to [47], the genus *Ceriops* is often found in monospecies stands on well-drained sites, in mangrove areas that are only reached by tides occasionally. *Avicennia marina* tends to be prominent in low and high intertidal forests, but is rarely abundant [42]. In open estuaries, such as those found around the mainland of South-eastern Australia, they are generally distributed between the MSL and MHHWN [48, 49]. Although *Excoecaria agallocha* and *Scyphiphora hidroyllacea* were also recorded above the MSL, these species mainly inhabit the zone from the MHHWS landward, even extending above the HAT. The root systems of these species allow for inundations of short duration, which is a major factor supporting their growth and survival in this elevation range [37].

Conclusions

The assessment of seawater level, inundation regime, and mangrove substrate elevation at the study site clearly delineated the planting zones appropriate for various mangrove species. The most appropriate elevation ranges for *Rhizophora stylosa*, *Rhizophora mucronata*, *Rhizophora apiculata*, *Sonneratia Alba*, and *Sonneratia caoselaris* is between the MLLWS and

MHHWS; however, these species, especially *Rhizophora stylosa*, can also grow below the MLLWS. Although *Bruguiera gymnorrhiza*, *Lumnitzera racemosa*, *Ceriops tagal*, and *Avicennia marina* can be found between the MLLWS and MHHWS, elevations close to the MLLWN are suggested as more suitable for *Bruguiera gymnorrhiza* and *Lumnitzera racemosa*. *Ceriops tagal* does best between MSL and MHHWS, whereas *Avicennia marina* prefers elevations between MHHWN and MHHWS. While it is suggested that both *Scyphiphora hydrophyllacea* and *Excoecaria agallocha* should ideally be planted between the MHHWS and HAT, *Scyphiphora hydrophyllacea* could also be planted above the HAT.

Acknowledgments

We want to thank the Directorate of Higher Education, Ministry of Research, Technology, and Higher Education of the Republic of Indonesia for financing this research with contract grant number: 005/SP2H/LT/DPRM/IV/2017 dated 20 April 2017. We also thank the Department of Marine Science, Universitas Hasanuddin (UNHAS) and the Government of Pangkep Regency for their support of this research.

References

- [1] C. Giri, E. Oching, L.L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek, N.C. Duke, *Status and distribution of mangrove forests of the world using earth observation satellite data*, **Global Ecology Biogeography**, **20**, 2011, pp. 154-159.
- [2] P.B. Tomlinson, **The Botany of Mangroves**, Cambridge University Press, Cambridge, United Kingdom, 1986, p. 413.
- [3] W. Giesen, S. Wulffraat, M. Zieren, L. Scholten, **Mangrove Guidebook for Southeast Asia**, FAO Regional Office for Asia and The Pacific, Bangkok, 2007, p. 186.
- [4] A. Malik, O. Mertz, R. Fensholt, *Mangrove forest decline: Consequences for livelihoods and environment in South Sulawesi*, **Regional Environmental Change**, **17**, 2017, pp. 157-169
- [5] A. Malik, A. Rahim, U. Sideng, A. Rasyid, J. Jumaddin, *Biodiversity assessment of mangrove vegetation for the sustainability of ecotourism in West Sulawesi, Indonesia*, **AACL Bioflux**, **12**(4), 2019, pp. 1458-1466.
- [6] A. Malik, A.R. Jalil, A. Arifuddin, A. Syahmuddin, *Biomass carbon stocks estimation in the mangrove rehabilitated area of Sinjai District, South Sulawesi, Indonesia*, **Geography, Environment, Sustainability**, 2020. <https://DOI-10.24057/2071-9388-2019-131>.
- [7] S.E. Hamilton, D. Casey, *Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21)*, **Global Ecology Biogeography**, **25**, 2016, pp. 729-738.
- [8] D.R. Richards, D.A. Friess, *Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012*, **Proceedings of the National Academy of Sciences of the United States of America**, **113**, 2016, pp. 344-349.
- [9] * * *, **The World's Mangroves 1980 – 2005**, FAO (Food and Agriculture Organization), FAO Forestry Paper 153, p. 77.
- [10] B. Brown, **Petunjuk Teknis Rehabilitasi Hidrologi Mangrove**, Mangrove Action Project dan Yayasan Akar Rumput Laut Indonesia, Yogyakarta, 2006, p. 54.
- [11] J.H. Primavera, J.M.A. Esteban, *A review of mangrove rehabilitation in the Philippines: Successes, Failures and Future Prospects*, **Wetland Ecology Management**, **16**, 2008, pp. 345–358.

- [12] M.S. Samson, R.N. Rollon, *Growth performance of planted mangroves in the Philippines: Revisiting forest management strategies*, **Ambio: A Journal of the Human Environment**, **37**, 2012, pp. 234–240.
- [13] D.A. Friess, K.W. Krauss, E.M. Horstman, T. Balke, T.J. Bouma, D. Galli, E.L. Webb, *Are all intertidal wetlands naturally created equal? Bottlenecks, thresholds and knowledge gaps to mangrove and saltmarsh ecosystems*, **Biological Reviews of the Cambridge Philosophical Society**, **87**, 2012, pp. 346–366.
- [14] B. Brown, R. Fadillah, Y. Nurdin, L. Soulsby, R. Ahmad, *Community based ecological mangrove rehabilitation (CBEMR) In Indonesia*, **Sapiens**, **7**, 2014, pp. 1-12.
- [15] S. Munandar, R.A. Suwignyo, Y. Okimoto, A. Nose, *Growth evaluation of rehabilitated mangroves in Indonesia with special emphasis on the relationship with soil and hydrological conditions*, **Journal of Agricultural Economics, Extension and Rural Development**, **1**, 2014, pp. 128-137.
- [16] A.F. Van Loon, B. Te Brake, M.H. Van Huijgevoort, R. Dijkma, *Hydrological classification, a practical tool for mangrove restoration*, **PLoSone**, **11**(3), 2016, Art. No. e0150302.
- [17] R.R.Y. Oh, D.A. Friess, B.M. Brown, *The Role of Surface Elevation in The Rehabilitation of Abandoned Aquaculture Ponds to Mangrove Forests, Sulawesi, Indonesia*, **Ecological Engineering**, **100**, 2017, pp. 325-334.
- [18] P. Laulikitnont, *Evaluation of mangrove ecosystem restoration success in Southeast Asia*, **Master's Projects, Paper 12**, The University of San Francisco, 2014, p. 61.
- [19] A.M. Ellison, *Mangrove restoration: Do we know enough?* **Restoration Ecology**, **8**, 2000, pp. 219-229.
- [20] A. Malik, R. Fensholt, O. Mertz, *Mangrove exploitation effects on biodiversity and ecosystem services*, **Biodiversity and Conservation**, **24**, 2015, pp. 3543-3557.
- [21] I.T.C. Wibisono, I.N. Suryadiputra, **Study of Lessons Learned from Mangrove/Coastal Ecosystem Restoration Efforts in Aceh Since the Tsunami**, Wetlands International – Indonesia Programme, Bogor, Indonesia, 2006, p. 86.
- [22] R.R. Lewis, *Mangrove restoration-costs and benefits of successful ecological restoration*. **Proceedings of the Mangrove Valuation Workshop**, Universiti Sains Malaysia, Penang, 2001, pp. 4-8.
- [23] K.W. Krauss, C.E. Lovelock, K.L. Mckee, L. López-Hoffman, S.M.L. Ewe, W.P. Sousa, *Environmental drivers in mangrove establishment and early development: A Review*, **Aquatic Botany**, **89**, 2008, pp. 105-127.
- [24] E. Gilman, J. Ellison, *Efficacy of alternative low-cost Approaches to mangrove restoration, American Samoa*, **Estuaries and Coasts**, **30**, 2007, pp. 641–651.
- [25] R.E. Brockmeyer, J.R. Rey, R.W. Virnstein, R.G. Gilmore, L. Earnest, *Rehabilitation of impounded estuarine wetlands by hydrologic reconnection to the Indian River Lagoon, Florida (USA)*, **Wetland Ecology Management**, **4**, 1996, pp. 93–109.
- [26] N. Matsui, J. Suekuni, M. Nogami, S. Havanond, P. Salikul, *Mangrove rehabilitation dynamics and soil organic carbon changes as a result of full hydraulic restoration and re-grading of a previously intensively managed shrimp pond*, **Wetland Ecology Management**, **8**, 2010, pp. 233-242.
- [27] N.J. Stevenson, R.R. III Lewis, P.R. Burbridge, *Disused shrimp ponds and mangrove rehabilitation*, **An International Perspective on Wetland Rehabilitation** (Editor: W. Streever), Springer, Netherlands. 1999.

- [28] A.R. Jalil, I. Yunus, **Spermonde: Kondisi Oseanografi Versus Ikan Pelagis**, Masagena Press Makassar, 2013, p. 124.
- [29] * * *, http://www.ppk-kp3k.kkp.go.id/direktori-pulau/index.php/public_c/pulau_info/8125 [Accessed on 15.01.2017].
- [30] H. Frick, **Ilmu dan alat ukur tanah**, Yayasan Kanisius, Jakarta, 1984, p. 181.
- [31] * * *, *Pemetaan dan kalkulasi kedalaman substrat pada lahan bakau*. **Laporan Penelitian (Research Report)**, USAID Indonesia, 2005, p. 41. (<http://www.docdatabase.net/more-pemetaan-dan-kalkulasi-kedalaman-substrat-pada-lahan-bakau-2696.html>).
- [32] T. Sawaragi, **Coastal Engineering-waves, Beaches, Wave-structure Interactions**, Vol. 78, 1995, Elsevier, p. 478.
- [33] Baharuddin, *Model pengaruh gelombang terhadap pantai Bau-Bau Propinsi Sulawesi Tengah tahun 1991-1995*, **Master Thesis**, Bogor Agricultural University, 2006.
- [34] J.I. Pariwono, *Kondisi pasang surut di Indonesia*, **Pasang surut** (Editors: S.R. Otto, S. Ongkosongo), Lembaga Ilmu Pengetahuan Indonesia, Pusat Penelitian dan Pengembangan Oseanologi, Jakarta. 1989.
- [35] A.D. Setyawan, Y.I. Ulumuddin, *Species diversity of Rhizophora in Tambelan Islands, Natuna Sea, Indonesia*, **Biodiversitas**, **13**, 2012, pp. 172-177.
- [36] P. Subardjo, *Studi morfologi guna pemetaan rob di pesisir Sayung, Kabupaten Demak, Jawa Tengah*, **Jurnal Ilmu Kelautan**, **9**, 2004, pp. 153-159.
- [37] Y.R. Noor, M. Khazali, I.N.N. Suryadiputra, **Panduan Pengenalan Mangrove di Indonesia**, second edition Pka/Wi-Ip (Wetlands International-Indonesia Programme), Bogor, 2006, p. 220.
- [38] K. Furukawa, E. Wolanski, *Sedimentation in mangrove forests*, **Mangroves and Salt Marshes**, **1**, 1996, pp. 3-10.
- [39] F. Suryawan, *Keanekaragaman vegetasi mangrove pasca tsunami di kawasan pesisir pantai timur Nangroe Aceh Darussalam*, **Biodiversitas**, **8**, 2007, pp. 262-265.
- [40] * * *, http://indonesiaforest.webs.com/manfaat_hutan_mangrove.pdf. [Accessed on 07.02.2017].
- [41] H. Halidah, *Avicennia marina (Forssk.) Vierh jenis mangrove yang kaya manfaat*, **Buletin Eboni**, **11**(1), 2014, pp. 37-44.
- [42] T.J. Smith, *Effects of light and intertidal position on seedling survival and growth in tropical tidal forests*, **Journal of Experimental Marine Biology and Ecology**, **110**, 1987, pp. 133-146.
- [43] S. Kitamura, C. Anwar, A. Chaniago, S. Baba, **Handbook of Mangroves in Indonesia: Bali and Lombok**, International Society for Mangrove Ecosystems, 1997, p. 119.
- [44] * * *, <https://mangrovemagz.com/2017/03/03/tujuh-tipe-akar-mangrove-yang-wajib-anda-ketahui/> [Accessed on 07.02.2018].
- [45] A.L. Robertson, D.M. Alongi, **Tropical Mangrove Ecosystems**, American Geophysical Union, Washington, DC, 1992, p. 329.
- [46] * * *, <http://www.iucnredlist.org/details/178846/0> [Accessed on 10.02.2017].
- [47] C.R. Sheue, Y.P. Yang, H.Y. Liu, F.S. Chou, S.C. Chang, P. Saenger, C.P. Mangion, G. Wightman, J.W.H. Yong, C.C. Tsai, *Reevaluating the taxonomic status of *Ceriops australis* (Rhizophoraceae) based on morphological and molecular evidence*, **Botanical Studies**, **50**, 2009, pp. 84-98.
- [48] N.C. Duke, *A systematic revision of the mangrove genus *Avicennia* (Avicenniaceae) in Australasia*, **Australia System Botany**, **4**, 1991, pp. 299-324.

- [49] P.J. Clarke, P.J. Myerscough, *The intertidal distribution of the Grey Mangrove (Avicennia Marina) in Southeastern Australia: The effects of physical conditions, interspecific competition, and predation on propagule establishment and survival*, **Australian Journal of Ecology**, **18**, 1993, pp. 307-315.
-

Received: October 2, 2019

Accepted: September 27, 2020