ASERS

Journal of Environmental Management and Tourism

Quarterly
Volume XIII
Issue 3(59)
Summer 2022
ISSN 2068 – 7729
Journal DOI
https://doi.org/10.14505/jemt

ASERS Publishing

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Volume XIII
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ASERS Publishing
http://www.asers.eu/asers-publishing
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DOI: https://doi.org/10.14505/jemt.13.3(59).17

Species Diversity of Mangroves in Central Zambales, Philippines

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Suggested Citation:

Serrano, S.C., Tangtham, N., Bualert, S. and Janyasuthiwong, S. (2022). Species Diversity of Mangroves in Central Zambales, Philippines. *Journal of Environmental Management and Tourism*, (Volume XIII, Summer), 3(59): 782 - 789. DOI:10.14505/jemt.v13.3(59).17

Article's History:

Received 23rd of December 2021; Received in revised form 21st of January 2022. Accepted 29th of April 2022; Published 3rd of June 2022.

Abstract:

The Philippines being an archipelagic country has one of the most diverse mangrove ecosystems. Species composition and diversity assessment are vital for sustainable management and conservation activities of mangrove resources. The diversity of mangroves was assessed to determine the status of the mangrove ecosystem in the central part of Zambales, Philippines. Data were gathered using a random quadrat sampling method in the twelve pre-selected stations. Each quadrat measures $10X12$ meters and the quantitative description of each plant species was determined. There were a total of 15 mangrove species surveyed in the area, under seven families, which family Rhizophoraceae was the most represented, with six species, and families Euphorbiaceae, Meliaceae, and Myrsinaceae were only represented with one species each. Shannon's Diversity Index showed that the mangrove ecosystems in Botolan had "very low" diversity (SDI=1.71) and Iba had "low" diversity (SDI=2.11). Anthropogenic sources such as agri-aqua and encroachment served as the major driving forces in the diversity of mangroves. Other threats include solid waste disposal, quarrying, oil spill, organic fertilizer run-off, and soil erosion among others. These may threaten species that could eventually cause greater biodiversity and economic loss. Hence, protection, conservation, and sustainable management be given priority.

Keywords: coastal ecosystem; coastal degradation; diversity; environmental degradation; mangroves

JEL Classification: Q57; Q30; R11.

Introduction

Mangrove forests are among the most productive ecosystems on Earth (Charrua *et al.* 2020).They are highly productive carbon-rich ecosystems as they receive nutrients both from sea and land and local populations rely on them for fuelwood, medicine, food from mangrove fisheries, timbers, and tannins (Aheto *et al.* 2016) However, mangroves are threatened by climate change (Gilman *et al.* 2008) and its value is being underestimated by being used as a sewage disposal sites and aquaculture pond development (Kathiresan and Bingham 2001; Camacho *et al.* 2020).

Coastal resource management is imperative to have a holistic and attainable management action. Mangrove and other resources profiling are necessary to formulate sustainable management and conservation plan, hence this study.

1. Review of Literature

In the Philippines, the majority of coastal communities rely on the services provided by mangrove ecosystems. Despite its services, mangrove areas in the country still declined by as much as 60% over the past eight decades (Garcia *et al.* 2014). It may be attributed to overexploitation by coastal dwellers, and conversion to agriculture, salt ponds, industry, and settlements (Primavera 2000). The impacts of climate change and the 2014 tsunami brought about by typhoon Haiyan have raised the profile and importance of mangroves in the country and the local communities play an important role in the rehabilitation and management of mangrove areas (Gevaña *et al.* 2019).

The province of Zambales, identified by the Department of Environment and Natural Resources (DENR) as one of the key biodiversity areas in the country is not spared from rapid destruction. The coastal ecosystems in the province have been facing a lot of pressure from anthropogenic activities that have been exacerbated by changing climate and the occurrence of natural hazards (Paz-Alberto *et al.* 2021). Mangrove diversity in other parts of the province mangroves is declining due to low species richness and uneven distribution of different species (Sigua *et al.* 2015). Paz Alberto *et al.* (2014) attributed the low diversity and population of mangroves in the nearby municipality of Masinloc, Zambales to human activities as the major factors.

2. Methodology

Biological assessment

The local name, number of individual mangrove species, and the quadrats where they were present were recorded. The data were used to compute the various environmental parameters such as frequency, relative frequency dominance, relative dominance, density, relative density, species importance value, and diversity index value. The mangroves were photographed in their natural habitat. Leaves, roots, flowers, and fruits were also recorded for identification by experts. Thereafter, the species recorded were categorized based on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

Table 1. Habitat criteria rating chart for mangroves

Condition	Criteria
Excellent	76% and above in % Crown Cover 1 Regeneration per m^2 Above 5m in average tree height Undisturbed to negligible disturbance
Good	51%-75% Crown Cover <1-0.76 Regeneration per m^2 <5m-3m average of trees Slight disturbance and few cuttings
Fair	26%-50% Crown Cover <0.50-0.75 Regeneration per m^2 <3m-2m average of trees Moderate disturbance and noticeable cuttings
Poor	0%-25% Crown Cover <0.50 Regeneration per m^2 <2m average of trees Heavy disturbance/cuttings/pollution, rampant conversion to other uses, nearly destroyed

Species diversity was computed and determined using the Shannon's Diversity Index (Smith and Smith, 1998 as cited by Paz-Alberto *et al.* 2015). Furthermore, the biodiversity indicator was also determined using the formula adapted from Dufrene and Legendre, 1997:

$$(IndVal_{ij} = A_{ij} \times B_{ij} \times 100) \quad 2.1$$

Where: A_{ij} = N individuals ij\ N individuals i

ij = the average amount of the species I in the zone (abundance)

i= mean values for species I in all zones

B_{ij} = N sites ij\ N sites i
ij = no. of sites in zones j where species i is present (frequency)
i = number of sites in zone j

Based on the derived ecological parameters, the status of the mangrove ecosystems was determined using the criteria developed by Deguit *et al.* 2004 (Table 1).

Sources and Level of Impacts of Environmental Degradation of the Coastal Ecosystems

The condition of the ecosystem was assessed through the checklist on the sources and level of impacts on environmental degradation of coastal ecosystems (Alberto 2005). Using the values of 1 – 4, evaluators from the academia, local government unit, and fishers determined the present condition of the forest ecosystem. The level of impact was estimated based on the percentage of impact or damage in the study area. The mean of the answers of the respondents was computed by summing up the answers for each level and then divided by the total number of respondents. A scale was used to interpret the levels of impacts on the environmental degradation of any ecosystem (Table 2).

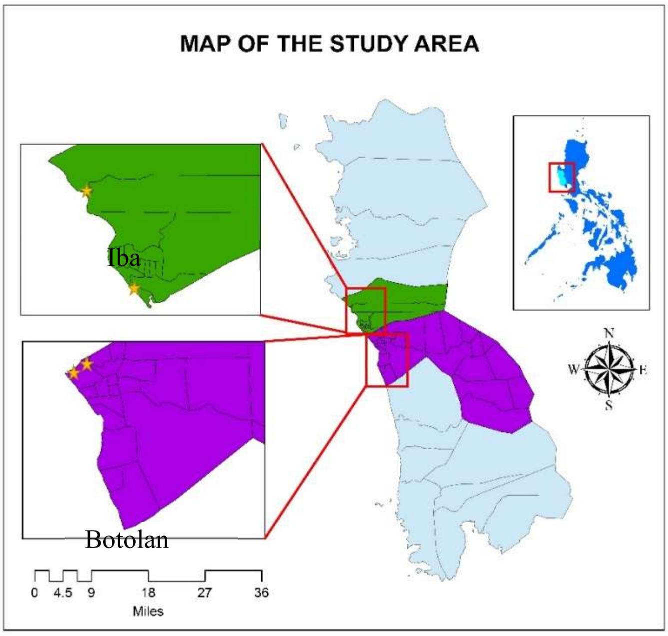
Table 2. The scale is used in the impact of environmental degradation levels.

Scale	Impact level
1.01 – 1.75	No Significant Impact
1.76 – 2.50	Small Impact
2.51 – 3.25	Moderate Impact
3.26 – 4.00	Major Impact

3. Results and Discussion

Zambales is the second largest province in Central Luzon, Philippines. Its shoreline stretches at around 175 kilometers facing the West Philippines Sea. There were four selected stations having three quadrats with an area of 10 m x 12 m. The study areas (Figure 1) were located in barangays Parel and Danacbunga, in the Municipality of Botolan (15°17'23"N 120°01'28"E) and barangays San Agustin and Lipay-Dingin-Pinagbuatan in the Municipality of Iba (15°20'N 119°59'E).

Figure 1. The showing the locations of the different stations.

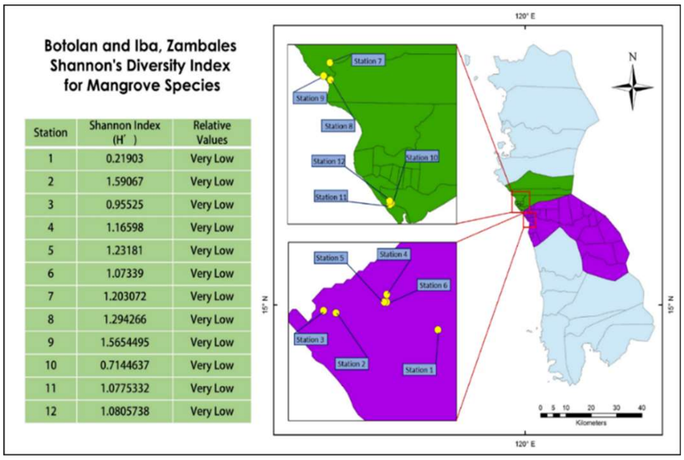


Mangrove Assessment

The Philippines has a rich collection of mangrove species thriving in the coastal ecosystems. Primavera (2000) identified 35 – 44 major and minor mangrove species belonging to 14 families. A total of fifteen mangrove species belonging to seven families were present in the sampling area. These were Euphorbiaceae (*Excoecaria agallocha);* Meliaceae (*Xylocarpus granatum*); Myrsinaceae (*Aegiceras cornilatum);* Rhizophoraceae (*Bruguiera cylindrica, Bruguiera sexangula, Ceriops decandra, Rhizophora apiculata, Rhizophora mucronata, Rhizophora* *stylosa)* Sonneratiaceae (*Sonneratia alba* and *Sonneratia caseolaris)*; Sterculiaceae *(Heritiera littoralis)* and Verbenaceae *(Avicennia marina, Avicennia officinalis and Avicennia rumphiana).*

Figure 2 shows the species diversity indices in the study areas with Station 1 (Danacbunga, Botolan) having the lowest diversity index. This can be attributed to the fact that the site which is just on the edge of a bridge and its adjacent areas are fishponds. Mangroves are being cleared to give easier access for pond maintenance. Station 9 (San Agustin, Iba) had the highest diversity index (1.56). It could be associated with the fact that the area is secluded and have limited access to the general public. The technical know-how of the residents nearby is also a plus factor.

Figure 2. Species diversity index of mangroves per station



Based on the ecological parameters computed, *S. alba* had the highest dominance value. It can be attributed to the fact that this species was used for the mangrove rehabilitation projects of the youth organizations. On the other hand, *E. agallocha* had the lowest dominance. Five species were considered indicator species of the studied area which had a 25% importance value index (IVI) and could be considered an indicator species according to Dufrene and Legendre. These were *S. alba* (66.61); *R. mucronate* (86.33); *S. caseolaris (*27.12); *B. sexangula* (36.85); *A. cornilatum* (43.80). Based on Shannon's Diversity Index, the mangrove ecosystems in the study areas at the Municipality of Botolan had very low mangrove diversity (SDI =1. 7428), Table 3.

Table 3. Computed ecological parameters of mangroves in Botolan, Zambales.

Species	IC	#QP	F	RF	D	RD	Do	RDo	IVI
Sonneratia alba	31	5	0.83	21.73	0.15	15.34	0.295	29.52	66.61
Rhizophora mucronata	80	4	0.66	17.39	0.39	39.60	0.293	29.34	86.33
Sonneratia caseolaris	19	3	0.5	13.04	0.09	9.40	0.046	4.67	27.12
Bruguiera sexangula	20	3	0.5	13.04	0.09	9.90	0.139	13.91	36.85
Bruguiera cylindrica	2	1	0.16	4.34	0.009	0.99	0.001	0.198	5.53
Rhizophora apiculata	15	1	0.16	4.34	0.07	7.42	0.029	2.91	14.68
Aegiceras cornilatum	30	3	0.5	13.04	0.14	14.85	0.159	15.90	43.80
Heritiera littoralis	3	1	0.16	4.34	0.01	1.48	0.025	2.56	8.40
Avicennia officinales	1	1	0.16	4.34	0.004	0.49	0.008	0.82	5.66
Excoecaria agallocha	1	1	0.166	4.34	0.004	0.49	0.001	0.13	4.97
									SDI = 1.74

Legend: IC- Individual count, #QP-Number of quadrat present, F-Frequency, RF-Relative frequency, D- Density, RD- Relative Density, Do-Dominance, RDo- Relative Dominance, IVI- Important Value Index, SDI- Shannon's Diversity Index

Moreover, in the Municipality of Iba, *A. officinalis* had the highest relative dominance value (29.03%), since most of the species observed were old-growth species. Species indicators in the area include *B. sexangula, A. officinalis, A. marina, R. stylosa, S. alba,* and *R. mucronata*, all having IVI of more than 25%. Generally, the mangrove ecosystems in Iba, Zambales have low diversity with the computed value of 2.11 SDI (Table 4).

Though various projects on coastal resources management like mangrove rehabilitation programs, regular mangrove tree planting activities, and policies promoting the conservation of mangrove ecosystems are being implemented, the mangrove diversity in Botolan still shows very low diversity while Iba exhibited low species diversity.

Table 4. Computed ecological parameters of mangroves in Iba, Zambales

Species	IC	#QP	F	RF	D	RD	Do	RDo	IVI
Excoecaria agallocha	6	1	0.166	3.70	0.024	2.47	0.008	0.80	6.98
Bruguiera cylindrica	6	1	0.166	3.70	0.024	2.47	0.009	0.97	7.16
Bruguiera sexangula	27	4	0.66	14.81	0.11	11.15	0.183	18.35	44.32
Avicennia officinalis	42	2	0.33	7.40	0.17	17.35	0.290	29.03	53.80
Avicennia marina	16	3	0.5	11.11	0.066	6.61	0.121	12.10	29.82
Rhizophora stylosa	63	3	0.5	11.11	0.26	26.03	0.073	7.35	44.49
Sonneratia caseolaris	4	4	0.66	14.81	0.016	1.65	0.015	1.51	17.98
Rhizophora apiculata	11	1	0.166	3.70	0.045	4.54	0.026	2.69	10.93
Sonneratia alba	30	3	0.5	11.11	0.12	12.39	0.139	13.94	37.45
Rhizophora mucronata	30	2	0.33	7.40	0.12	12.39	0.072	7.23	27.03
Avicennia rumphiana	1	1	0.166	3.70	0.004	0.41	0.003	0.39	4.51
Xylocarpus granatum	3	1	0.166	3.70	0.012	1.23	0.053	5.36	10.30
									SDI= 2.11

Legend: IC- Individual count, #QP-Number of quadrat present, F-Frequency, RF-Relative frequency, D- Density, RD- Relative Density, Do-Dominance, RDo- Relative Dominance, IVI- Important Value Index, SDI- Shannons Diversity Index

This could be attributed to various factors such as illegal cutting of mangroves and reclamation of riverbanks. However, there is still a prospect for the conservation of ecosystems. Three stilt mangroves considered the most important of all mangrove genera across the Pacific tropical region were observed in the area with high importance value indices (*R. stylosa*, *R. mucronate,* and *R. apiculata*). The regeneration rate of mangroves in five stations was excellent (Table 5).

Table 5. Status of mangroves ecosystems.

Station	Measurement		Status
	Crown Cover (%)	Regeneration Rate (per m^2)	
Station 1 (Danacbunga, Botolan	73.62	0.47	Good
Station 2 (Danacbunga, Botolan)	87.50	0.90	Excellent
Station 3 (Parel, Botolan)	68.15	4.53	Good
Station 4 (Parel, Botolan)	91.18	2.35	Excellent
Station 5 (Parel, Botolan)	89.88	2.07	Excellent
Station 6 (Parel, Botolan)	83.12	0.70	Excellent
Station 7 (San Agustin, Iba)	62.55	0.35	Good
Station 8 (San Agustin, Iba)	68.36	1.80	Good
Station 9 (San Agustin, Iba)	90.02	0.56	Excellent
Station 10 (LDP, Iba)	49.23	0.15	Fair
Station 11 (LDP, Iba)	74.58	0.24	Good
Station 12 (LDP, Iba)	70.22	0.20	Good

Mangrove ecosystems in the site served an important role to the community. It become the source of food and income for residents, especially during this pandemic. Residents were not able to go for commercial fishing during the restricted period of quarantine, particularly from March to July 2020. The disruption of the fishing activities resulted in temporary unemployment for fisher folks. Also, tourism which usually gives local communities income has been stopped. Alternative livelihood activities were carried out by residents like fishing in mangroves areas. In setting up their traps, mangrove trunks were being cut and used as fences. This activity leads to the destruction of the ecosystem.

All surveyed mangrove species were listed in the IUCN Red List 2021-1. *Avicennia rumphiana* was listed as "vulnerable" with decreasing population on a global scale. *Ceriops decandra* on the other hand was listed as "near threatened" with decreasing population and the rest of the mangrove species were "least concern" and decreasing in the population (Table 6).

A. rumphiana and *C. decandra* were categorized as vulnerable and near threatened respectively, in the IUCN Red List of threatened species. *A. rumphiana*'s low diversity in the world is attributed to its role in the human population. Its seeds are boiled and eaten in other countries, it is sold as vegetables, and woods are harvested for timber (Giesen 2006). In the study area, the timbers are harvested and sold in the form of charcoal used for smoking fish. This corroborates the statement by Duke (2006) that mangroves in Pacific areas are harvested for firewood and charcoal production.

Table 6. Ecological status based on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species

Species	Ecological Status IUCN 2021-1
Aegiceras cornilatum	Decreasing /Least Concern (Ellison, *et al.* 2010a)
Avicennia marina	Decreasing /Least Concern (Duke, *et al.* 2010a)
Avicennia officinalis	Decreasing /Least Concern (Duke, *et al.* 2010b)
Avicennia rumphiana	Decreasing /Vulnerable (Duke, *et al.* 2010c)
Bruguiera cylindrica	Decreasing /Least Concern (Duke, *et al.* 2010d)
Bruguiera sexangula	Decreasing /Least Concern (Duke, *et al.* 2010e)
Ceriops decandra	Decreasing /Near Threatened (Duke, *et al.* 2010f)
Excoecaria agallocha	Decreasing /Least Concern (Ellison, *et al.* 2010b)
Heritiera littoralis	Decreasing /Least Concern (Duke, *et al.* 2010g)
Rhizophora apiculata	Decreasing /Least Concern (Duke, *et al.* 2010h)
Rhizophora mucronata	Decreasing/Least Concern (Duke, *et al.* 2010i)
Rhizophora stylosa	Decreasing/Least Concern (Ellison, *et al.* 2010c)
Sonneratia alba	Decreasing/Least Concern (Kathiresan, *et al.* 2010a)
Sonneratia caseolaris	Decreasing/Least Concern (Kathiresan, *et al.* 2010b)
Xylocarpus granatum	Decreasing/Least Concern (Ellison, *et al.* 2010d)

Major sources of environmental degradation

Based on the questionnaire-guided interview conducted, results showed that the major environmental degradation observed in the area were solid waste disposal, quarrying, oil spillage, and inorganic fertilizer run-off. Recreational development and pond culture fish production posed a small impact on the ecosystems (Table 7). This corroborates with the studies of Nguyen (2014) and Primavera (2000) that aquaculture development urbanization, conversion to agriculture, overharvesting for industrial uses such as timber and charcoal serve as the significant causes of mangrove degradation.

Table 7. Major sources of environmental degradation observed

Sources of environmental degradation	Computed value	Interpretation
Solid wastes	3.80	Major Impact
Quarrying	3.59	Major Impact
Environmental aesthetic degradation	3.50	Major Impact
Oil spill	3.48	Major Impact
Inorganic fertilizer run-off hazards	3.44	Major Impact
Volcanic eruption/lahar deposits	3.43	Major Impact
Soil erosion	2.48	Moderate Impact
Sedimentation	2.39	Moderate Impact
Dredging	1.61	Small Impact
Recreational development	1.47	Small Impact
Tourism	1.44	Small Impact
Encroachment	1.14	Small Impact
Pond to culture fish	1.02	Small Impact

Conclusion

Results of the study inferred that the diversity, distribution, and dominance of mangrove trees highly depend on the ecological and environmental conditions. A diverse and stable system could be attained as long as these driving forces are favorable to the system. However, threats such as improper waste disposal, quarrying, oil spill, conversion to agri-aqua activities, and encroachment affect the status of mangroves in the area specifically mangroves with the highest importance value.

The efforts of the local communities, particularly the local government units to protect the remaining mangrove is vital for the future of these species. Policies and programs that provide incentives to those largely depending on mangrove ecosystems should be developed. In addition, the information campaign for the protection of the mangrove ecosystems needs to be strengthened. Involving all members of the community so that the efforts of those actively involved will not be put to waste. Technical assistance, training, and livelihood programs to enhance the capability of locals may decrease their dependency on mangrove ecosystems. Lastly, managing the relationship between mangroves and their environment is imperative for a resilient and stable system.

Acknowledgments

The authors gratefully acknowledged funding support from the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). Warm appreciation is also extended to the faculty and staff of Central Luzon State University, Nueva Ecija Philippines, and the Faculty of Environment, Kasetsart University, Bangkhen, Bangkok for their technical support. More so, gratitude to the people of Zambales, Philippines for their guidance and help during the fieldwork.

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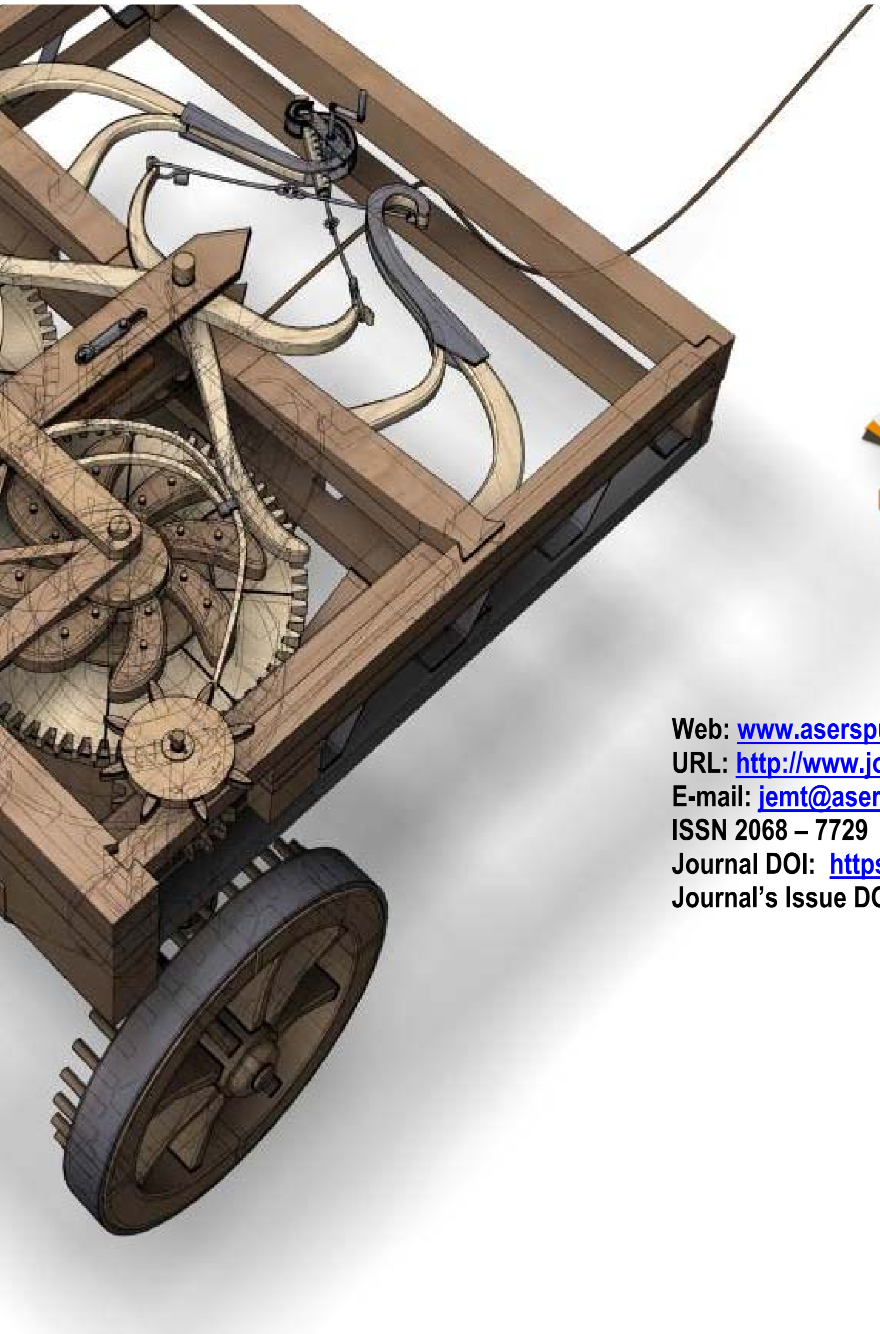

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Journal's Issue DOI: https://doi.org/10.14505/jemt.v13.3(59).00