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International Journal of Grey Systems is devoted to advancing the theory and practice of Grey System Theory as a novel mathematical approach to soft computing and computational intelligence. The journal is particularly interested in manuscripts that are backed by theory rather than tradition and can lead us to develop a scientifically rigorous body of knowledge on the Grey System Theory. Innovative ideas to manage uncertain systems that have the potential to create a debate are also of interest. Being the first open-access journal on the Grey System Theory, it is hoped to play a decisive role in mainstreaming the Grey System Theory by improving its understanding and global outreach. The journal seeks to foster communications between young and seasoned scholars and between scholars and practitioners with a view to aid data analysts, problem solvers, and decision-makers in handling complex problems objectively.

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In the memory of Professor Deng Julong (1933 - 2013),

the founder of Grey System Theory

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Editorial

Forty years back, Deng Julong submitted a manuscript to *Systems & Control Letters*. Upon its publication, the study marked the birth of the Grey System Theory (GST). Today, the GST, with mathematics at its core, has become an important alternative approach to soft computing and computational intelligence. Its successes in energy forecasts and multiple criteria decision-making are no secret. However, it still faces many challenges, at least in the near-term future. Some scholars outside China still hold a narrow view of it as a 'Chinese science,' while others, who are less concerned with practice and more with theory, have other reservations. Because the predominant literature on the GST is in the Chinese language and the other literature available in the 'English-like' language raises more questions than it answers, it is no wonder why many are still afraid to bell the cat! However, as a late Chinese leader said, "It doesn't matter if a cat is black or white, so long as it catches mice." The cat we are dealing with is grey, and it catches mice. However, how it catches, is still not clear on many.

International Journal of Grey Systems has been launched to bring clarity, transparency, and diversity to our field. It is an international journal that publishes the English language works on the theory and practice of the GST. Unlike its experienced contemporaries, the journal strongly encourages reviewing the English language literature in its pages. If a study is built on a body of literature that is largely inaccessible or unreadable to our international readers, it should be submitted elsewhere. When we say the journal is 'international,' we mean it. Being the first open-access journal on the GST, it is hoped that the journal would play a decisive role in the coming years in mainstreaming the GST by improving its understanding and global outreach. The journal is particularly interested in manuscripts that are backed by theory rather than tradition and can lead us to develop a scientifically rigorous body of knowledge on the GST.

"A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it," says Max Planck. *International Journal of Grey Systems* intends to fulfill the needs of the new generation of data analysts and problem solvers and wishes together they take our field to new heights in the future. Feel free to join us in our journey, which is tough but exciting.

Finally, we wish to thank everyone who played some role in the journal's launch. Everybody who worked on our manuscript submission system. Our reviewers, editors, copyeditors, and producers. Also, the authors who entrusted us with their submissions and the readers who will read, share and cite these works. We also thank the Grey Systems Society of Pakistan for its indispensable support. Last but not least, I'm indebted to Professor Liu Sifeng for his encouragement and motivation. His words are still resonating in my ears; "[I] wish the journal will become a window and a garden plot for grey systems research, become a bridge…to link colleagues of theoretical research and practical application…." We hope our journey toward success is as beautiful as the people who supported us.

International Journal of Grey Systems does not just communicate with you; it also listens to you. Thus, whenever a proposal comes to your mind, that can benefit it and the scientific community it serves, feel free to discuss. It is hoped that in the *International Journal of Grey Systems,* you will find not merely another outlet for your future submissions but also a window to see further.

Saad Ahmed Javed
Editor-in-chief

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Evaluation of Low-Carbon Sustainable Technologies in Agriculture Sector through Grey Ordinal Priority Approach

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Abstract: The agriculture sector plays a vital role in the economy, society, and environment, the three dimensions of sustainability. The agriculture sector contributes 12% to 14% of global greenhouse gas (GHG) emissions to the atmosphere, negatively impacting climate change. Using low-carbon and sustainable agricultural technologies can help mitigate climate change and global food security issues. But selecting and prioritizing the best technologies among all alternatives has always been an issue for decision-makers because of various uncertainty related to the agricultural sector. Therefore, the current study intends to identify and prioritize the key low-carbon and sustainable agricultural technologies. The current study makes a pioneering attempt in employing the Grey Ordinal Priority Approach (OPA-G), a modern multi-attribute decision-making technique, for the evaluation of low-carbon and sustainable technologies for the agricultural sector.

Keywords: Low-carbon; agricultural technology; grey system theory; multiple criteria decision making; grey ordinal priority approach; sustainable development

1. Introduction

Reducing emissions from agricultural activities is a global issue getting exceeding attention these days. For minimizing the carbon emissions from the agriculture sector, the role of low carbon technologies is hard to ignore. The agriculture-related activities produce emissions that negatively affect the environment. These emissions are usually associated with livestock, burning of crop residues, using N fertilizer, agricultural soil, enteric fermentation, biomass burning, deforestation etc. (Khan, 2020). Studies have argued that sustainable agricultural technologies can play an essential role in achieving low carbon agriculture plans (Vinholis *et al.*, 2021) and ensuring green food production for resource conservation (Zaman, 2020). Unlike the emissions from other energy-intensive economic sectors, the agriculture sector's greenhouse gas emissions are usually underestimated (McMahon, 2019). Agriculture-related activity directly contributes 12%-14% of global greenhouse gas (GHG) emissions to the atmosphere (Beach *et al.*, 2008; Tian *et al.*, 2011). China, India, Brazil, and the USA are the biggest emitter of GHG from the agricultural sector. Agricultural activity in other developing countries is also growing at a fast pace (Bennetzen *et al.*, 2016), indicating greater emissions in the future. The current study recognizes this fact and tries to highlight the issue of greenhouse gas emissions from the agriculture sector and its implications for sustainable development and food security issues. Notably, low-carbon and sustainable agricultural technologies can help agricultural sectors of different countries reduce emissions.

It is always difficult to select suitable technologies for the agricultural industry (Ren *et al.*, 2017). Hence, considering sustainable criteria such as economic, social, and environmental, it has become even more difficult for the decision-makers to select the best low-carbon and sustainable technologies for the agricultural industry. However, multiple criteria decision-making (MCDM) is a popular technique to identify the best alternative among all possible alternatives based on different conflicting criteria. Thus, numerous decision-making methods have been proposed to date to solve MCDM problems. For example, Wang *et al.* (2018) used the Fuzzy AHP-VIKOR method to prioritize sustainable energy technology for the agricultural sector. Yu *et al.* (2019), Memari *et al.* (2019), and Li *et al.* (2019) applied the TOPSIS method for selecting the best suppliers for different industries. Amindoust (2018) and Ghadimi *et al.* (2018) used a fuzzy inference system to deal with the uncertainty in supplier selection. These studies proved the wide acceptance of MCDM methods among scholars. However, considering the variety of applications in decision-making methods, it is observed that there are many limitations in existing MCDM models (Mahmoudi *et al.*, 2020). Javed *et al.* (2020) classified uncertainty in MCDM methods into five classes, as shown in Figure 1.

In light of the above discussion, the current study attempts to find a reliable solution for the decision-makers so that they can select the best possible alternatives based on different criteria. The present study uses the Grey Ordinal Priority Approach (OPA-G), a modern multi-attribute decision-making technique, to evaluate low-carbon and sustainable agricultural technologies while dealing with most of the problems mentioned above.

The rest of the study is organized as follows. Section two describes the reviews of literature related to the role of agriculture in sustainable development goals (SDGs), finds the primary sources of emissions from the agricultural sector, and identified the critical low-carbon and sustainable agriculture technology that can play an important role in mitigating climate change and provide global food security. Grey Ordinal Priority Approach (OPA-G) model is also explained. Section three develops the Grey Ordinal priority approach (OPA-G), a modern multi-attribute decision-making model that will help evaluate low-carbon and sustainable agricultural technologies. Section four describes the result and discussion of the OPA-G model, and finally, the study will conclude with essential suggestions and implications for the countries where agriculture plays a vital role in the economy and maintaining food security.

2. Literature Review

2.1 Role of Agriculture Sector in Sustainable Development

The concept of sustainable development (SD) is relatively new, but, today it is one of the most widely discussed topics worldwide. According to the United Nations Bruntland Commission Report (1987), it is the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The agriculture sector is a key sector contributing to sustainable development (Smith *et al.*, 2014). According to FAO (2020.), among 17 sustainable development goals (SDGs) promoted by the United Nations, SDG1, SDG2, and SDG13 are directly linked to the Agricultural sector. To achieve sustainability in the agricultural sector, it must meet the present and future generations' needs by ensuring all the sustainability dimensions (economic, social and environmental) (FAO, 2021). But climate change poses the biggest threat to the agricultural sector; global agricultural production and food security already has been compromised due to climate change (IPCC, 2012). Growing evidence indicates that Climate change, agriculture, and global food security are closely linked to each other (Huo & Huo., 2019; Ray *et al.*, 2015; Hatfield *et al.*, 2014; Wheeler & Braun, 2013; Olesen *et al.*, 2011). It is important to note that agricultural production also has a negative impact on the environment, e.g., various agricultural activities such as tillage, livestock, burning of crop residues, using N fertilizer, agricultural soil, enteric fermentation, biomass burning, deforestation etc. release a huge amount of anthropogenic greenhouse gas (GHG) to the atmosphere (Li *et al.*, 2021; Vetter *et al.*, 2017). They have also argued that adopting low carbon and sustainable agricultural technology can help mitigate climate change and achieve sustainable development.

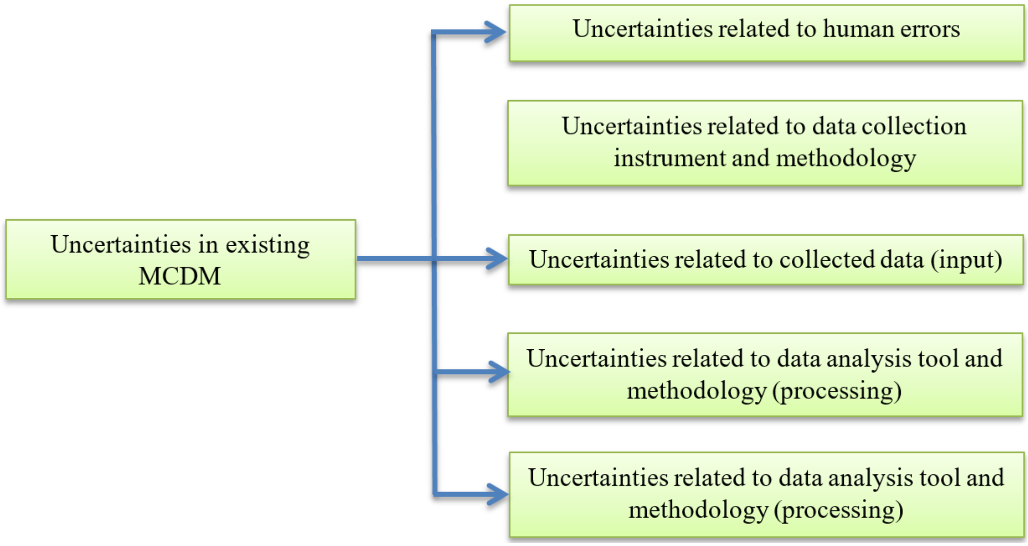

Figure 1. Five-dimensional uncertainties in MCDM methods (Source: Javed *et al.*, 2020)

2.2 Overview of Greenhouse Gases Emissions from Agriculture Sector

Agricultural activities directly contribute greenhouse gas (GHG) emissions to the atmosphere (Beach *et al.*, 2008; Tian *et al.*, 2011). Paustian *et al.* (2016) highlighted that 10% – 14% of global GHG emissions are related to agricultural production. A study by World Resources Institute has argued that the agricultural sector is the world's second-largest GHG emitter, after the energy sector, and this trend is less likely to change in the future (Russell, 2014). Unless taking any action to mitigate climate change, GHG emissions from the agricultural sector will reach 58% by 2050 (Arcipowska *et al.*, 2019). However, currently, GHS emissions from the agriculture sector are estimated at approximately 60% from Africa and Latin America, 30% from Asia, and 10% from Europe and North America (Anuga *et al.*, 2020). Considering the last twenty years, 1996 – 2016, China, India, the USA, and Brazil were the most responsible countries for GHG emissions from the agricultural sector. 37% of global agricultural GHG emission comes from these four countries (Arcipowska *et al.*, 2019). Similarly, agricultural GHG emissions in other regions such as Africa also rises dramatically in the last 20 years. Average annual GHG emissions from the agriculture sector increase between 2.9% to 3.1%, while in China and India, it has increased by 16% and 14%, respectively. Meanwhile, Australia, Argentina, and Brazil are the top three countries for agricultural emission in terms of per capita (Tongwane & Moeletsi, 2018). Many studies have documented that the primary sources of GHG emissions from the agricultural sector are livestock, burning of crop residues, use of N fertilizer, enteric fermentation, biomass burning, deforestation etc. (Lybbert & Sumner. 2012; Khan *et al.*, 2020; EU, 2020). See Figure 2 for details. Moreover, many researchers have pointed that there is a tremendous opportunity to mitigate a substantial amount of GHG from the agriculture sector through changes in agricultural management practice in different regions around the world; China (Li *et al.*, 2021; Huo & Huo, 2019), India (Pathak *et al.*, 2012), Brazil (Vinholis *et al.*, 2021), Europe (EU, 2020), France (Meynard *et al.*, 2018), Sub-Saharan Africa (Powlson *et al.*, 2016), South America (De *et al.*, 2017), these changes are closely related to low–carbon and sustainable agriculture technologies which can help the agricultural sector to mitigate climate change by reducing GHG emission and drive towards global food security and sustainable development.

2.3 Causes of CO_2 Emissions from Agriculture Sector

Like other industries, the agricultural sector is also responsible for producing a huge amount of carbon dioxide (CO_2). Several studies have been executed to find the leading causes of CO_2 emission from the agricultural sector. Agricultural management practices, such as tillage, residues management,

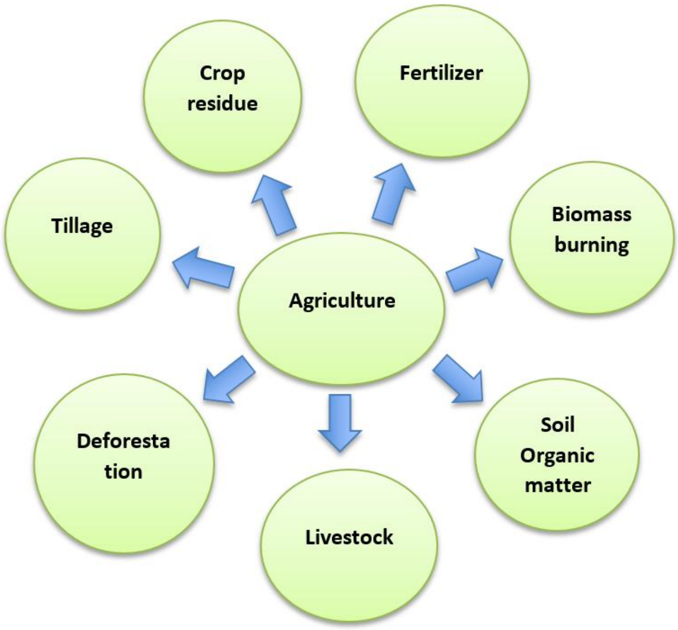

Figure 2. Primary sources of carbon emission from the agricultural sector

fertilizer management, are the key sources of CO_2 fluxes from agriculture to the atmosphere (Khan *et al.*, 2020; Sikora *et al.*, 2020). The use of fossil fuel in different agricultural operations, manufacturing of fertilizer, and pesticides are also responsible for producing CO_2 (Bhatia *et al.*, 2012; Redman *et al.*, 2020). Soil is the largest pool of CO2, storing about 2344PgC of soil organic carbon SOC (Jobbágy & Jackson., 2000). There is considerable evidence in the literature that confirms that conventional tillage system release protected SOC by disturbance and disruption of the soil, causing the soil to release a substantial amount of CO_2 into the atmosphere (Dimassi *et al.*, 2014; Luo *et al.*, 2010; Ussiri & Lal, 2009; Six *et al.*, 2004). Abdalla *et al.* (2016) have argued that soil management (especially tillage systems) plays a crucial role in CO_2 emission from agriculture. Using a Meta-Analysis, they have observed that a no-tillage system can reduce up to 21% of CO_2 emissions than the conventional tillage system, which can significantly help mitigate climate change. However, not only tillage system contributes CO_2 emission to the atmosphere, but leftover material from agriculture (crop residues) also contains a high amount of CO_2 (Cardoen *et al.*, 2015). Considering ten years from 2003 to 2013, Cherubin *et al.* (2018) documented that the world has produced 3830 million metric tons (MT) of crop residues from agriculture. Deshavath *et al.* (2019) reported that in 2016 alone top four agricultural production countries – China, India, the USA, and Brazil – have burnt 181.8 MT of crop residues in open fields, contributing 15.8 MT of CO_2 emission to the earth's atmosphere. It is happening not because of farmer's unawareness of the environmental impact of open burning of crop residues but because of a lack of idea and information about low-carbon and cost-effective technologies (Kumar & Singh, 2021). Prasad *et al.* (2020) argued that crop residues have tremendous potential for producing renewable energy. Using the Life cycle assessment (LCA) method, they have shown that proper utilization of crop residues can play a vital role in cutting down net CO2 emissions and reducing the climate footprint from agriculture.

2.4 Identification of Low-Carbon Sustainable Technologies in the Agriculture Sector

Many studies have tried to identify and evaluate low carbon and sustainable agricultural technologies. Table 1 summarizes the literature on low carbon and sustainable agricultural technologies' evaluation. Based on the review of literature, the current study identified the following low carbon and sustainable agricultural technologies for potential evaluation:

Table 1. Summary of literature on low carbon and sustainable agricultural technologies' evaluation

Year	Description	Country of focus	Evaluation technique	Reference
2012	The study identified six low carbon technologies	India	Scenario-based analysis	Pathak *et al.* (2012)
2016	The study identified Conservation Agriculture as a critical sustainable agricultural technology for the mitigation potential of climate change and food security	Sub-Saharan Africa	Meta-analysis	Powlson *et al.* (2016)
2015	The study identified integrated soil fertility management (ISFM) as a key technology for increasing food security and GHG mitigation potential	N/A	N/A	Roobroeck *et al.* (2015)
2015	The study identified 6 agricultural technologies with great mitigation potential	China	Bottom-up assessment	Lybbert and Sumner (2012)
2016	The study identified a No-tillage system as a key agricultural technology for reducing CO_2 emissions	N/A	Meta-analysis	Abdualla *et al.* (2016)
2017	The study identified six low carbon technology (RDPLi, NT, ICLFS, BNF, PCFF, IAW)	South America	Scenario-based analysis	De *et al.* (2017)
2017	This study identified 9 low carbon and sustainable agricultural technology	N/A	Qualitative approach	Uppala *et al.* (2016)
2018	The study identified Crop diversification as a key sustainable agricultural technology	France	Threefold approach	Meynard *et al.* (2018)
2019	The study identified two sustainable agricultural technology-based different criteria	China	A fuzzy AHP-VIKOR	Wang *et al.* (2019)
2019	The study identified one sustainable agricultural technology (SRI)	Mali	Qualitative approach	Mwalupaso *et al.* (2019)
2020	The study identified Agroforestry as an important agricultural technology for food security, increasing resilience, and mitigating climate change	Southern Malawi	Double hurdle specification with a control function approach	Amadu *et al.* (2020)
2020	The study identified five low carbon technology	Africa	Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach.	Anuga *et al.* (2020)
2020	The study identified ten low carbon technologies	China	Theory of Planned Behavior	Li *et al.* (2020)
2020	The study identified crop rotation as a sustainable agricultural technology based on different criteria	India	AHP-GIS	Singha *et al.* (2020)
2020	The study identified SWC and WH as important sustainable agricultural technology.	Ethiopia	Qualitative approach	Yaekob *et al.* (2020)
2020	The study identified ICLS and ICLFS as a viable low carbon technology	Brazil	Econometric regression models	Vinholis *et al.* (2021)
2021	The current study identifies (and prioritizes, based on selected criteria) nine low carbon agricultural technology, e.g., ICLS, ICLFS, No-tillage, CS, etc.	N/A	Grey Ordinal Priority Approach (OPA-G)	The current study

*ICLS: Integrated Crop Livestock System; ICLFS: Integrated Crop-Livestock System; CS: Carbon Sequestration; SWC: Soil and Water Conservation; WH: water harvesting

2.4.1 Integrated crop-livestock systems (T1). Integrated crop-livestock systems (ICLS) are diversified agricultural production systems that can enhance food production and contribute to sustainable intensification while improving environmental quality by reducing net GHG emissions (Moraes *et al.*, 2019). ICLS advances ecological interaction between different natural resources such as (crops, animals, and grassland) and reduces the need for chemical fertilizers and other inputs by developing organic fertilization from livestock waste (Hendrickson *et al.*, 2008). This low-carbon and sustainable technology are very important for sustainability, increasing profitability, and economic stability (Russelle *et al.*, 2007). However, despite economic, social, and environmental benefits, farmers' workload becomes a significant concern for this technology (Moraine *et al.*, 2014).

2.4.2 No-tillage (T2). The no-tillage system is an agriculture technique that helps mitigate CO_2 emissions from dry land by avoiding soil disturbance, reports Abdalla *et al.* (2016). Their study finds that conventional tillage system emits 21% more CO_2 than No-tillage system. It is a popular agricultural technology worldwide because of its ability to maximize soil water infiltration, reduce soil erosion, and increase organic carbon stock (Page *et al.*, 2019). However, Powlson *et al.* (2014) focused on its benefits and limitations. They suggested this low carbon agricultural technology significantly impacts soil properties, crop growth, and the environment. These technologies' key benefits are; increased rainfall infiltration, Increased soil biological activity, Increased crop yields, decreased risk of soil erosion, labor/time saved through avoiding tillage operations, reduced costs, and CO_2 emission by elimination of fossil fuel use in tillage operations. However, despite many benefits, they have also argued that this technology has some limitations in the long term. For example, crop yields may remain unchanged in some situation, nitrous oxide emissions may increase, extra labor force for weed control may be needed, in wet climates planting crops may be delayed, machinery for planting crops may not be available in less developed countries, and farm income may not increase in near term.

2.4.3 Integrated crop-livestock-forest system (T3). According to Vinholis *et al.* (2020), an integrated crop-livestock-forest system (CLFS) is an agro-ecosystem management practice that can improve the soil's biological, chemical, and physical conditions. This low carbon agricultural technique combines different farming systems such as crop–forest, crop-livestock, forest–livestock, and crop-livestock–forest (Valani *et al.* 2021). This technology's benefit includes increasing cycling and nutrient utilization efficiency, reducing production costs, and protecting climate change by reducing GHG emissions.

2.4.4 Conservation agriculture (T4). Conservation agriculture (CA) technology is considered a greener solution for mitigating negative impacts from the agricultural sector (Gilbert, 2012). It is a potential cropping system that can minimize the adverse effects of declining soil fertility and minimize environmental degradation (Kassam *et al.*, 2009). This modern agricultural technique can enable farmers in different parts of the world to achieve sustainable agricultural production (Hobbs *et al.* 2008). Large-scale farmers located in various regions such as North America, South America, Australia, New Zealand are benefiting by adopting CA technology (Kassam *et al.*, 2009). Despite many complementariness, there are some constraints and challenges for adopting CA technology, especially in small-scale farming linked to limited resources such as land, labor, capital etc. (Valbuena *et al.*, 2012). However, its advantages outweigh its limitations.

2.4.5 Integrated Soil Fertility Management (T5). Integrated Soil Fertility Management (ISFM) is considered a means of enhancing crop productivity and maximizing agronomic inputs' efficiency, thus contributing to sustainable intensification (Vanlauwe *et al.*, 2015). ISFM is climate-smart agriculture (CSA) practices associated with cropping, fertilizers, organic resources, and other processes in addition to increasing agricultural production and input use efficiency. In the long run, ISFM provides productivity gains, increased resilience, and mitigation benefits (Roobroeck *et al.*, 2015). Despite the usefulness of ISFM for food security, farmers' income and environmental protection lack of awareness and disbeliefs about ISFM become a significant concern for adopting this low-carbon and sustainable agricultural technology (Lambrecht *et al.* 2016).

2.4.6 Agroforestry (T6). The concept of agroforestry is an association of trees with crops or livestock on the same land that embraces a broad range of systems under different management schemes (Martin

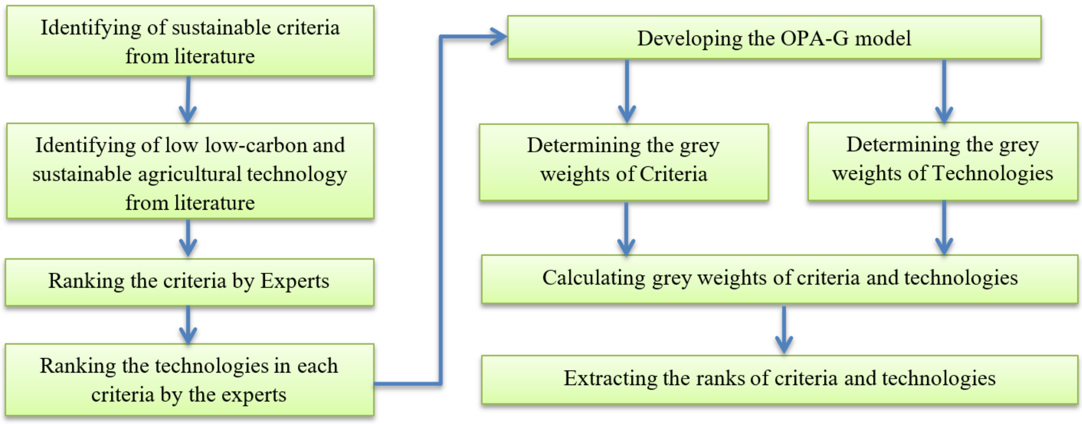

Figure 3. The framework of the study

et al., 2019), which can provide many benefits, including increase crop yields, reduce soil erosion, conserving biodiversity and increasing soil fertility (Nair *et al.* 2010; 2009). De Stefano and Jacobson (2018) argued that agroforestry could be a viable opportunity to tackle the climate change issues, reducing CO_2 emissions from the agricultural sector. Considering all these benefits, Waldron *et al.* (2017) argued that agroforestry could help to increase global food security and, in the meantime, can help to achieve SDGs.

2.4.7 Carbon sequestration (T7). Carbon sequestration is the process of balancing carbon dioxide into an atmospheric C pool. Carbon sequestering in the agricultural sector requires a change in agricultural management practices such as pesticide use, irrigation, and machinery (West & Marland, 2002). This technology has a considerable potential to reduce CO_2 emissions from the agriculture sector and fossil fuel emissions (Schlesinge, 1999). This process gains enormous attention as an alternate way to help stem the rate of greenhouse gas growth and associated changes in our climate. Scientist prioritizes carbon sequestration as the primary goal with ancillary improvements in water management, soil erosion, and food security.

2.4.8 Crop diversification (T8). The agricultural sector is the most sensitive to the climate change issue. Studies have documented a direct link to climate change and agricultural production, more likely negative impacts than positive (Li *et al.*, 2021; Huo & Huo, 2019; Birthal & Hazrana, 2019). Crop diversification has a great potentiality to increase the sustainability of arable farming systems that minimize the inputs of (irrigation water, fertilizers, pesticides) expanding the heterogeneity of habitat mosaics, or reducing yield gap associated with too frequent returns of the same species (Meynard *et al.*, 2018). Birthal and Hazrana (2019) have found that crop diversification has many benefits in the long run. On the other hand, Magrini *et al.* (2016) and Lithourgidis *et al.* (2011) argued that historically established to support large-scale specialization, selection of appropriate crops, and short-term maximization of profits with chemical inputs are the main barriers to the adaption of this technology.

2.4.9 Soil and water conservation (T9). Soil and water conservation (SWC) is a sustainable agriculture management system that reduces soil erosion, increases agricultural production yield, and grows organic carbon stock (Mekonnen, 2020; Adimassu *et al.*, 2017). However, different scholars have shown that the impact of SWC technology has inconsistent results on crop yield and economic profitability in the short-run (Kato *et al.*, 2011; Kassie *et al.*, 2011). As a result, farmer's adaption rate to this technology is meagre. Asfaw *et al.* (2017) pointed out that inadequate information, poor skills, and inadequate transportation and communication are responsible for this technology's low adaption, especially in developing countries.

2.5 Grey Ordinal Priority Approach

2.5.1 Grey system theory. Deng Julong introduced the Grey System Theory in 1982 (Ju-Long, 1982) where a white–grey–black spectrum is used to explain the uncertainty of a system (Hao *et al.*, 2006). Grey System Theory has a wide range of popularity among researchers from different fields because of its applicability to solve real-world situations where incomplete information and uncertainty exist. The key areas of Grey System Theory include grey relational analysis, grey generating space, grey forecasting, grey decision making, grey control, and grey mathematics. Grey System Theory has seen application in numerous fields, including agriculture (Tan *et al.*, 2014), supplier selection (Mahmoudi *et al.*, 2021a), economic growth analysis (Huang *et al.*, 2020), health care management (Aydemir & Sahin, 2019; Javed and Liu., 2018), sustainable development (Ikram *et al.*, 2021; Abid *et al.*, 2021), environment (Hao *et al.*, 2006), electromagnetic data processing (Jiang *et al.*, 2017), traffic flow prediction (Xiao *et al.*, 2020), energy and emissions (Chen *et al.*, 2021; Zhu *et al.*, 2019), project management (Sheikh *et al.*, 2019; Javed & Liu, 2019), machine learning (Xie *et al.*, 2021; Ma, 2019), among others. It can be seen that the application of Grey System Theory is widespread and multi-disciplinary. Some researchers even argued its superiority over other methods such as fuzzy set theory, considering the ability and flexibility of dealing with ambiguity and uncertainty, independence over membership function, and ability to handle a small sample size (Chithambaranathan *et al.*, 2015; Ng and Deng, 1995). Grey Ordinal Priority Approach is a new multi-criteria decision-making technique that fuses the advantages of grey system theory with the Ordinal Priority Approach (OPA) and is discussed in the subsequent section.

2.5.2 Grey Ordinal Priority Approach. The ordinal priority approach (OPA) is an emerging multi-criteria decision-making (MCDM) technique developed by Ataie *et al.* (2020) and has recently seen some extensions. They argued that this model has a strong capability of supporting both single and group decision-making. Also, it can calculate the weights for different experts, criteria, and alternatives simultaneously, while most other MCDM models only can produce a ranking of alternatives based on the expert's opinion. The recent literature has demonstrated the OPA's effectiveness with interesting results. For example, Mahmoudi *et al.* (2020a) showed the suitability of the OPA-based framework for problems involving big data. Mahmoudi *et al.* (2021b) proposed the Fuzzy Ordinal Priority Approach to solve the decision-making problems through linguistic information.

Grey Ordinal Priority Approach (OPA-G) is another important member of the OPA family and was proposed by Mahmoudi *et al.* (2021a). They demonstrated its effectiveness in solving sustainable supplier selection problems. They have shown that OPA-G can work without any linguistic variable or pairwise comparison-based data and have a high capability of dealing with greyness/uncertainty. While considering the ordinal priorities, the OPA-G model can provide the weights for experts, criteria, and alternatives. Table 2 shows the explanation of sets, indexes, variables, and the parameters of the OPA-G model (Mahmoudi *et al.*, 2021a).

Table 2. Sets, indexes, variables, and parameters of the OPA-G model

sets	
I	Set of experts $\forall i \in I$
J	Set of criteria $\forall j \in J$
K	Set of alternatives $\forall k \in K$
Indexes	
i	Index of the experts $(1, \ldots, p)$
j	Index of preference of the criteria $(1, \ldots, n)$
k	Index of the alternatives $(1, \ldots, m)$
Variables	
$\otimes Z$	Grey objective function
$\otimes W_{ijk}^{r}$	Grey weight (importance) of k^{th} alternative based on j^{th} criterion by i^{th} expert at r^{th} rank
Parameters	
$\otimes i$	Grey rank of the expert i
$\otimes j$	Grey rank of the criterion j
$\otimes r$	Grey rank of the alternative k

Table 3. The demographic profile of the respondents

Gender	Male (70%) Female (30%)
Age	More than 50 years old (20%) 41 – 50 years old (30%) 31 – 40 years old (20%) 21 – 30 years old (30%)
Industry	Agriculture, Forestry and Other Land Use (80%) Other (20%)
Position/post	Top level manager (40%) Middle level manager (40%) Junior level manager (20%)
Work Experience	More than 12 years (40%) 9 - 12 years (20%) 7 – 9 years (10%) years 4 – 6 years (20%) 1 – 3 years (10 %)
Organization type	Public (50%) Private (50%)
Total sample	10

Understanding of some definitions is mandatory before the computational steps of the OPA-G are discussed. These definitions are defined below and are adapted from Mahmoudi *et al.* (2020).

Definition I: Grey number $\otimes A$ is described as follows:

$$\otimes \mathrm{A} = [\underline{A}, \overline{A}], \qquad \underline{A} < \overline{A} \tag{1}$$

where, $\underline{A}$ is the lower limit and $\overline{A}$ is the upper limit of the grey number $\otimes A$. Here, it should be noted that a grey number should not be confused with interval. Unlike an interval, a grey number is a crisp number, and its interval merely represents greyness in the exact location of this crisp number.

Definition II: Assume that A is a crisp number. Therefore, $\otimes A$ has a grey rank [Rank(A) − 0.5, Rank(A) + 0.5]. Equation (2) should be utilized to convert crisp rank n to grey rank n.

$$\mathrm{Rank} \otimes n[n - 0.5, n + 0.5] \tag{2}$$

Definition III: Assume that the expert(s) is not confident about in a choice of two ranks *x* and *y* for a criterion or an alternative while *x* < *y*. Then, Eq. (3) should be utilized for the grey rank:

$$\mathrm{Rank}(\otimes x, \otimes y) = [\mathrm{Rank}\ (x) - 0.5, \mathrm{Rank}\ (y) + 0.5] \tag{3}$$

The relevant computational steps of the OPA-G model are as follows (see Figure 3):

Step 1: First, the decision-makers need to determine the necessary criteria.

Step 2: The decision-makers must identify and select the relevant experts.

Step 3: The experts should give ranking to different criteria. If experts also doubt about the exact priority level for different criteria, they can utilize Definitions II and III.

Step 4: Determining the ranking for available alternatives in each criterion. In this step, experts still can use Definitions II and III to converts crisp rank into grey rank.

Step 5: After collecting all the data needed in Step 1 to Step 4 the OPA-G model should be solved using Eq. (4)

$$Max \ \otimes Z \tag{4}$$

S.t. ($\forall i, j, k$ and r):

$$\otimes Z \leq \otimes i \left(\otimes j \left(r(\otimes W_{ijk}{}^{r} - \otimes W_{ijk}{}^{r+1})\right)\right)$$

$$\otimes Z \leq \otimes i \otimes j \otimes m \otimes W_{ijk}{}^{m}$$

$$\sum_{i=1}^{p}\sum_{j=1}^{n}\sum_{k=1}^{m} \otimes W_{ijk} = [0.8, 1.2]$$

$$\otimes W_{ijk} \geq 0$$

where, $\otimes Z$ is unrestricted in sign.

To obtain the individual weights of criteria and alternatives, Eqs. (5) and (6) should be employed respectively.

$$W_j = \sum_{i=1}^{p}\sum_{j=1}^{n} W_{ijk} \quad \forall j \tag{5}$$

$$W_k = \sum_{i=1}^{p}\sum_{j=1}^{n} W_{ijk} \quad \forall k \tag{6}$$

Step 6: After getting all the weights of experts, criteria, and alternatives, the grey possibility degree should be calculated by the following matrix to extract the ranking of alternatives.

$$GP_{ij} = \begin{bmatrix} P(W_1 \leq W_1) & P(W_1 \leq W_2) \ldots . P(W_1 \leq W_k) \\ P(W_2 \leq W_1) & P(W_2 \leq W_2) \ldots . P(W_2 \leq W_k) \\ & . \\ & . \\ & . \\ P(W_k \leq W_1) & P(W_k \leq W_2) \ldots . P(W_k \leq W_k) \end{bmatrix} \tag{7}$$

Finally, the following matrix results

$$P_{ij} = \begin{bmatrix} p_{w1}p_{w1} & p_{w1}p_{w2} \cdots \cdots p_{w1}p_{wk} \\ p_{w2}p_{w1} & p_{w2}p_{w2} \cdots \cdots p_{w2}p_{w1} \\ & . \\ & . \\ & . \\ p_{wk}p_{w1} & p_{wk}p_{w2} \cdots \cdots p_{wk}p_{wk} \end{bmatrix} \tag{8}$$

By summing up all the horizontal component of P_{ij} we can get the ranking for an individual alternative. The highest value will represent the best alternative for selection.

3. Research Methodology

3.1 Data Collection and Analysis

Data were collected from a designed survey where experts were selected in a random process from 10 different countries and fields. Following the sustainability approach, we identified three different criteria (Economic, Social, and Environmental) to evaluate low carbon and sustainable agricultural technologies. Then expert opinions were sought to prioritize those criteria on a 1-3 point scale where 1 represents high priority 3 represents low priority. Table 4 shows the opinion of experts regarding the evaluation of different criteria. Based on those criteria, experts were then asked to evaluate all the available alternatives/technologies on the same processes. Demographic information of the experts is available in Table 3. The data collected from them is available in Tables 5, 6, and 7. Microsoft Excel was utilized for making tables and performing calculations, Google forms were utilized for preparing the questionnaire and then data collection. Lingo 9.0 software was utilized for building the OPA-G model and its execution.

3.2 The model

Because of the limited space, the model for one expert and three criteria is developed and shown below to introduce the readers to the model structure. In the current study, ten experts and nine criteria were involved, and the complete model was very lengthy, and thus is shown in the Appendix available at *zeonodo* (i.e., Shajedul, 2021). The key is islamislam.

$$Max = \frac{1}{2} * \overline{Z} + \frac{1}{2} * \underline{Z};$$

$S.t.$

!Expert 1 !Criteria 1

$$1.5 * 1.5 * 1.5 * (\underline{W}_{11}T_1 - \underline{W}_{11}T_2) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * (\overline{W}_{11}T_1 - \overline{W}_{11}T_2) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * (\underline{W}_{11}T_2 - \underline{W}_{11}T_4) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * (\overline{W}_{11}T_2 - \overline{W}_{11}T_4) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * (\underline{W}_{11}T_4 - \underline{W}_{11}T_5) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * (\overline{W}_{11}T_4 - \overline{W}_{11}T_5) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * (\underline{W}_{11}T_5 - \underline{W}_{11}T_8) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * (\overline{W}_{11}T_5 - \overline{W}_{11}T_8) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * (\underline{W}_{11}T_8 - \underline{W}_{11}T_9) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * (\overline{W}_{11}T_8 - \overline{W}_{11}T_9) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * (\underline{W}_{11}T_9 - \underline{W}_{11}T_3) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5(\overline{W}_{11}T_9 - \overline{W}_{11}T_3) \geq \underline{Z};$$

$$1.5 * 1.5 * 2.5(\underline{W}_{11}T_3 - \underline{W}_{11}T_7) \geq \overline{Z};$$

$$0.5 * 0.5 * 1.5(\overline{W}_{11}T_3 - \overline{W}_{11}T_7) \geq \underline{Z};$$

$$1.5 * 1.5 * 2.5(\underline{W}_{11}T_7 - \underline{W}_{11}T_6) \geq \overline{Z};$$

$$0.5 * 0.5 * 1.5(\overline{W}_{11}T_7 - \overline{W}_{11}T_6) \geq \underline{Z};$$

$$1.5 * 1.5 * 3.5 * (\underline{W}_{11}T_6) \geq \overline{Z};$$

$$0.5 * 0.5 * 2.5 * (\overline{W}_{11}T_6) \geq \underline{Z};$$

!Expert 1 !Criteria 2

$$1.5 * 2.5 * 1.5 * (\underline{W}_{12}T_2 - \underline{W}_{12}T_4) \geq \overline{Z};$$

$$0.5 * 1.5 * 0.5 * (\overline{W}_{12}T_2 - \overline{W}_{12}T_4) \geq \underline{Z};$$

$$1.5 * 2.5 * 1.5 * \left(\underline{W}_{12}T_4 - \underline{W}_{12}T_7\right) \geq \overline{Z};$$

$$0.5 * 1.5 * 0.5 * \left(\overline{W}_{12}T_4 - \overline{W}_{12}T_7\right) \geq \underline{Z};$$

$$1.5 * 2.5 * 1.5 * \left(\underline{W}_{12}T_7 - \underline{W}_{12}T_9\right) \geq \overline{Z};$$

$$0.5 * 1.5 * 0.5 * \left(\overline{W}_{12}T_7 - \overline{W}_{12}T_9\right) \geq \underline{Z};$$

$$1.5 * 2.5 * 1.5 * \left(\underline{W}_{12}T_9 - \underline{W}_{12}T_3\right) \geq \overline{Z};$$

$$0.5 * 1.5 * 0.5 * \left(\overline{W}_{12}T_9 - \overline{W}_{12}T_3\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * \left(\underline{W}_{12}T_3 - \underline{W}_{12}T_5\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * \left(\overline{W}_{12}T_3 - \overline{W}_{12}T_5\right) \geq \underline{Z};$$

$$1.5 * 2.5 * 2.5 * \left(\underline{W}_{12}T_5 - \underline{W}_{12}T_6\right) \geq \overline{Z};$$

$$0.5 * 1.5 * 1.5 * \left(\overline{W}_{12}T_5 - \overline{W}_{12}T_6\right) \geq \underline{Z};$$

$$1.5 * 2.5 * 2.5 * \left(\underline{W}_{12}T_6 - \underline{W}_{12}T_8\right) \geq \overline{Z};$$

$$0.5 * 1.5 * 1.5 * \left(\overline{W}_{12}T_6 - \overline{W}_{12}T_8\right) \geq \underline{Z};$$

$$1.5 * 2.5 * 2.5 * \left(\underline{W}_{12}T_8 - \underline{W}_{12}T_8\right) \geq \overline{Z};$$

$$0.5 * 1.5 * 1.5 * \left(\overline{W}_{12}T_8 - \overline{W}_{12}T_8\right) \geq \underline{Z};$$

$$1.5 * 2.5 * 3.5 * \left(\underline{W}_{12}T_8\right) \geq \overline{Z};$$

$$0.5 * 1.5 * 2.5 * \left(\overline{W}_{12}T_8\right) \geq \underline{Z};$$

!Expert 1 !Criteria 3

$$1.5 * 1.5 * 1.5 * \left(\underline{W}_{13}T_2 - \underline{W}_{13}T_3\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * \left(\overline{W}_{13}T_2 - \overline{W}_{13}T_3\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * \left(\underline{W}_{13}T_3 - \underline{W}_{13}T_4\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * \left(\overline{W}_{13}T_3 - \overline{W}_{13}T_4\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * \left(\underline{W}_{13}T_4 - \underline{W}_{13}T_6\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * \left(\overline{W}_{13}T_4 - \overline{W}_{13}T_6\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * \left(\underline{W}_{13}T_6 - \underline{W}_{13}T_7\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * \left(\overline{W}_{13}T_6 - \overline{W}_{13}T_7\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * \left(\underline{W}_{13}T_7 - \underline{W}_{13}T_9\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * \left(\overline{W}_{13}T_7 - \overline{W}_{13}T_9\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 1.5 * \left(\underline{W}_{13}T_9 - \underline{W}_{13}T_5\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 0.5 * \left(\overline{W}_{13}T_9 - \overline{W}_{13}T_5\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 2.5 * \left(\underline{W}_{13}T_5 - \underline{W}_{13}T_8\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 1.5 * \left(\overline{W}_{13}T_5 - \overline{W}_{13}T_8\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 2.5 * \left(\underline{W}_{13}T_8 - \underline{W}_{13}T_1\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 1.5 * \left(\overline{W}_{13}T_8 - \overline{W}_{13}T_1\right) \geq \underline{Z};$$

$$1.5 * 1.5 * 3.5 * \left(\underline{W}_{13}T_1\right) \geq \overline{Z};$$

$$0.5 * 0.5 * 2.5 * \left(\overline{W}_{13}T_1\right) \geq \underline{Z};$$

$$\overline{W}_{11}T_1 + \overline{W}_{11}T_2 + \overline{W}_{11}T_3 + \overline{W}_{11}T_4 + \overline{W}_{11}T_5 + \overline{W}_{11}T_6 + \overline{W}_{11}T_7 + \overline{W}_{11}T_8 + \overline{W}_{11}T_9 + \overline{W}_{12}T_1 + \overline{W}_{12}T_2 + \overline{W}_{12}T_3 + \overline{W}_{12}T_4 + \overline{W}_{12}T_5 + \overline{W}_{12}T_6 + \overline{W}_{12}T_7 + \overline{W}_{12}T_8 + \overline{W}_{12}T_9 + \overline{W}_{13}T_1 + \overline{W}_{13}T_2 + \overline{W}_{13}T_3 + \overline{W}_{13}T_4 + \overline{W}_{13}T_5 + \overline{W}_{13}T_6 + \overline{W}_{13}T_7 + \overline{W}_{13}T_8 + \overline{W}_{13}T_9 = 1.2;$$

$$\underline{W}_{11}T_1 + \underline{W}_{11}T_2 + \underline{W}_{11}T_3 + \underline{W}_{11}T_4 + \underline{W}_{11}T_5 + \underline{W}_{11}T_6 + \underline{W}_{11}T_7 + \underline{W}_{11}T_8 + \underline{W}_{11}T_9 + \underline{W}_{12}T_1 + \underline{W}_{12}T_2 + \underline{W}_{12}T_3 + \underline{W}_{12}T_4 + \underline{W}_{12}T_5 + \underline{W}_{12}T_6 + \underline{W}_{12}T_7 + \underline{W}_{12}T_8 + \underline{W}_{12}T_9 + \underline{W}_{13}T_1 + \underline{W}_{13}T_2 + \underline{W}_{13}T_3 + \underline{W}_{13}T_4 + \underline{W}_{13}T_5 + \underline{W}_{13}T_6 + \underline{W}_{13}T_7 + \underline{W}_{13}T_8 + \underline{W}_{13}T_9 = 0.8;$$

$$\overline{Z} \geq \underline{Z};$$

$$\overline{W}_{11}T_1 \geq \underline{W}_{11}T_1; \overline{W}_{11}T_2 \geq \underline{W}_{11}T_2; \overline{W}_{11}T_3 \geq \underline{W}_{11}T_3; \overline{W}_{11}T_4 \geq \underline{W}_{11}T_4; \overline{W}_{11}T_5 \geq \underline{W}_{11}T_5; \overline{W}_{11}T_6 \geq \underline{W}_{11}T_6; \overline{W}_{11}T_7 \geq \underline{W}_{11}T_7; \overline{W}_{11}T_8 \geq \underline{W}_{11}T_8; \overline{W}_{11}T_9 \geq \underline{W}_{11}T_9; \overline{W}_{12}T_1 \geq \underline{W}_{12}T_1; \overline{W}_{12}T_2 \geq \underline{W}_{12}T_2; \overline{W}_{12}T_3 \geq \underline{W}_{12}T_3; \overline{W}_{12}T_4 \geq \underline{W}_{12}T_4; \overline{W}_{12}T_5 \geq \underline{W}_{12}T_5; \overline{W}_{12}T_6 \geq \underline{W}_{12}T_6; \overline{W}_{12}T_7 \geq \underline{W}_{12}T_7; \overline{W}_{12}T_8 \geq \underline{W}_{12}T_8; \overline{W}_{12}T_9 \geq \underline{W}_{12}T_9; \overline{W}_{13}T_1 \geq \underline{W}_{13}T_1; \overline{W}_{13}T_2 \geq \underline{W}_{13}T_2; \overline{W}_{13}T_3 \geq \underline{W}_{13}T_3; \overline{W}_{13}T_4 \geq \underline{W}_{13}T_4; \overline{W}_{13}T_5 \geq \underline{W}_{13}T_5; \overline{W}_{13}T_6 \geq \underline{W}_{13}T_6; \overline{W}_{13}T_7 \geq \underline{W}_{13}T_7; \overline{W}_{13}T_8 \geq \underline{W}_{13}T_8; \overline{W}_{13}T_9 \geq \underline{W}_{13}T_9;$$

$$\underline{W}_{11}T_1, \underline{W}_{11}T_2, \underline{W}_{11}T_3, \underline{W}_{11}T_4, \underline{W}_{11}T_5, \underline{W}_{11}T_6, \underline{W}_{11}T_7, \underline{W}_{11}T_8,$$

$$\underline{W}_{11}T_9, \underline{W}_{12}T_1, \underline{W}_{12}T_2, \underline{W}_{12}T_3, \underline{W}_{12}T_4, \underline{W}_{12}T_5, \underline{W}_{12}T_6, \underline{W}_{12}T_7,$$

$$\underline{W}_{12}T_8, \underline{W}_{12}T_9, \underline{W}_{13}T_1, \underline{W}_{13}T_2, \underline{W}_{13}T_3, \underline{W}_{13}T_4, \underline{W}_{13}T_5, \underline{W}_{13}T_6,$$

$$\underline{W}_{13}T_7, \underline{W}_{13}T_8, \underline{W}_{13}T_9 \geq 0.$$

4. Data and results

The study involves three sustainability criteria, ten experts, and nine different alternatives that can be seen from Tables 4 to 7. It is important to note that the study considered all the experts to be of equally important. However, it is worth noting that the OPA-G can calculate the experts' weights as well, if needed. After solving the model, weights and ranking for criteria and alternatives are shown in Tables 8 and 9. To obtain the weights of criteria and alternatives, Eqs. (5) and (6) are employed. Afterward, to extract the ranking for criteria and alternatives matrix P_{ji} has been estimated using Eq. (8).

Table 4. Experts' opinions regarding importance of different criteria

Experts	*Rank Type*	*Economic criterion (C1)*	*Social criterion (C3)*	*Environmental criterion (C2)*
E1	Crispy Rank (CR)	1	2	1
	Grey Rank (GR)	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]
E2	Crispy Rank (CR)	1	2	1
	Grey Rank (GR)	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]
E3	Crispy Rank (CR)	1	3	2
	Grey Rank (GR)	[0.5,1.5]	[2.5,3.5]	[1.5,2.5]
E4	Crispy Rank (CR)	1	2	1
	Grey Rank (GR)	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]
E5	Crispy Rank (CR)	1	3	2
	Grey Rank (GR)	[0.5,1.5]	[2.5,3.5]	[1.5,2.5]
E6	Crispy Rank (CR)	1	1	1
	Grey Rank (GR)	[0.5,1.5]	[0.5,1.5]	[0.5,1.5]
E7	Crispy Rank (CR)	2	2	1
	Grey Rank (GR)	[1.5,2.5]	[1.5,2.5]	[0.5,1.5]
E8	Crispy Rank (CR)	1	2	1
	Grey Rank (GR)	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]
E9	Crispy Rank (CR)	2	3	1
	Grey Rank (GR)	[1.5,2.5]	[2.5,3.5]	[0.5,1.5]
E10	Crispy Rank (CR)	2	3	1
	Grey Rank (GR)	[1.5,2.5]	[2.5,3.5]	[0.5,1.5]

Table 5. Opinion of experts for the technologies against Economic criteria

Experts	*Rank Type*	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*T7*	*T8*	*T9*
E1	CR	1	1	2	1	1	3	2	1	1
	GR	[0.5,1.5]	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]	[0.5,1.5]	[2.5,3.5]	[1.5,2.5]	[0.5,1.5]	[0.5,1.5]
E2	CR	1	2	4	2	4	5	1	3	2
	GR	[0.5,1.5]	[1.5,2.5]	[3.5,4.5]	[1.5,2.5]	[3.5,4.5]	[4.5,5.5]	[0.5,1.5]	[2.5,3.5]	[1.5,2.5]
E3	CR	1	5	2	5	2	3	4	1	4
	GR	[0.5,1.5]	[4.5,5.5]	[1.5,2.5]	[4.5,5.5]	[1.5,2.5]	[2.5,3.5]	[3.5,4.5]	[0.5,1.5]	[3.5,4.5]
E4	CR	1	5	2	3	5	4	6	3	4
	GR	[0.5,1.5]	[4.5,5.5]	[1.5,2.5]	[2.5,3.5]	[4.5,5.5]	[3.5,4.5]	[5.5,6.5]	[2.5,3.5]	[3.5,4.5]
E5	CR	1	5	1 or 2	3	6	4	3	2 or 3	5
	GR	[0.5,1.5]	[4.5,5.5]	[0.5,2.5]	[2.5,3.5]	[5.5,6.5]	[3.5,4.5]	[2.5,3.5]	[1.5,3.5]	[4.5,5.5]
E6	CR	1	2	1	1	2	1	2	1	1
	GR	[0.5,1.5]	[2.5,3.5]	[0.5,1.5]	[0.5,1.5]	[2.5,3.5]	[0.5,1.5]	[2.5,3.5]	[0.5,1.5]	[0.5,1.5]
E7	CR	1	6	3	5	7	4	8	2	9
	GR	[0.5,1.5]	[5.5,6.5]	[2.5,3.5]	[4.5,5.5]	[6.5,7.5]	[3.5,4.5]	[7.5,8.5]	[2.5,3.5]	[8.5,9.5]
E8	CR	1	4	2	3	4	3	5	2	5
	GR	[0.5,1.5]	[3.5,4.5]	[2.5,3.5]	[2.5,3.5]	[3.5,4.5]	[2.5,3.5]	[4.5,5.5]	[2.5,3.5]	[4.5,5.5]
E9	CR	1	5	2	3	5	4	5	6	7
	GR	[0.5,1.5]	[4.5,5.5]	[2.5,3.5]	[2.5,3.5]	[4.5,5.5]	[3.5,4.5]	[4.5,5.5]	[5.5,6.5]	[6.5,7.5]
E10	CR	2	4	3	1	4	3	5	1	4
	GR	[2.5,3.5]	[3.5,4.5]	[2.5,3.5]	[0.5,1.5]	[3.5,4.5]	[2.5,3.5]	[4.5,5.5]	[0.5,1.5]	[3.5,4.5]

Agricultural activity is the lifeline for human civilization. However, it is also a source of some adverse effects environment which are usually overlooked. Identifying and selecting appropriate low-carbon and sustainable technologies for the agriculture sector can reduce these adverse effects. Thus the current study identified the best low-carbon and sustainable agricultural technologies and then applied OPA-G methods to evaluate those technologies. After analyzing all experts' opinions, results show that all these technologies have some potential to be used in the agriculture sector to handle global climate change agricultural sustainability issues with varying degrees of priority. The current study finds that among all the available alternatives, integrated crop-livestock systems (ICLS), T1, constitute the best technology that can enhance food production and contribute to sustainable development while improving environmental quality by reducing net GHG emissions. The literature from different regions supports this finding. For example, Vinholis *et al.* (2021) showed that Brazil has already taken the initiative to adapt ICLS to its agriculture sector as a voluntary target of reducing emissions. By 2020 Brazil has adopted about 4 million hectares of land under ICLS and avoided 22.11 million tons of carbon dioxide (MAPA, 2019). In North America, Russelle *et al.* (2007) suggested that farmers should adapt ICLS technology to enhance firms' profitability and environmental sustainability. However, from Table 4, one can easily see the ranking of all available technologies. Figure 4 shows complete ranking.

In terms of sustainability criteria, results suggest all these technology has some viable potentiality to be used in the agricultural sector and the literature also suggests the same. But the current study did not find any literature that has suggested ranking for low carbon and sustainable agricultural technology under uncertainty. Therefore, the current study employed the OPA-G model to handle the uncertainty related to the agricultural sector and find the ranking among different alternatives. With the aid of the OPA-G method, decision-makers can genuinely enjoy a high level of flexibility in dealing with various sustainable criteria and uncertainty. Moreover, the OPA-G method does not require data normalization, a pairwise comparison matrix, and aggregating experts' opinions.

Table 6. Opinion of experts for the technologies against Social criteria

Experts	*Rank Type*	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*T7*	*T8*	*T9*
E1	CR	3	1	2	1	2	2	1	2	1
	GR	[2.5,3.5]	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]	[1.5,2.5]	[1.5,2.5]	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]
E2	CR	1	4	5	3	4	3	2	2	3
	GR	[0.5,1.5]	[3.5,4.5]	[4.5,5.5]	[2.5,3.5]	[3.5,4.5]	[2.5,3.5]	[1.5,2.5]	[1.5,2.5]	[2.5,3.5]
E3	CR	2	3	4	2	3	1	4	4	5
	GR	[1.5,2.5]	[2.5,3.5]	[3.5,4.5]	[1.5,2.5]	[2.5,3.5]	[0.5,1.5]	[3.5,4.5]	[3.5,4.5]	[4.5,5.5]
E4	CR	2	3	1	2	4	1	2 or 3	2	5
	GR	[1.5,2.5]	[3.5,4.5]	[0.5,1.5]	[1.5,2.5]	[3.5,4.5]	[0.5,1.5]	[1.5,3.5]	[1.5,2.5]	[4.5,5.5]
E5	CR	2	3	1	4	3	5	3	2	3
	GR	[1.5,2.5]	[3.5,4.5]	[0.5,1.5]	[3.5,4.5]	[3.5,4.5]	[4.5,5.5]	[3.5,4.5]	[1.5,2.5]	[3.5,4.5]
E6	CR	1	2	1	1	2	3	1	2	1
	GR	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]	[0.5,1.5]	[1.5,2.5]	[3.5,4.5]	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]
E7	CR	5	8	4	6	2	1	9	3	7
	GR	[4.5,5.5]	[7.5,8.5]	[3.5,4.5]	[5.5,6.5]	[1.5,2.5]	[0.5,1.5]	[8.5,9.5]	[3.5,4.5]	[6.5,7.5]
E8	CR	5	3	4	4	3	2	1	3	4
	GR	[4.5,5.5]	[3.5,4.5]	[3.5,4.5]	[3.5,4.5]	[3.5,4.5]	[1.5,2.5]	[0.5,1.5]	[3.5,4.5]	[3.5,4.5]
E9	CR	4	2	3	4	2	5	5	4	2
	GR	[3.5,4.5]	[1.5,2.5]	[3.5,4.5]	[3.5,4.5]	[1.5,2.5]	[4.5,5.5]	[4.5,5.5]	[3.5,4.5]	[1.5,2.5]
E10	CR	3	4	4	5	5	3	1	3	5
	GR	[3.5,4.5]	[3.5,4.5]	[3.5,4.5]	[4.5,5.5]	[4.5,5.5]	[3.5,4.5]	[0.5,1.5]	[3.5,4.5]	[4.5,5.5]

Table 7. Opinion of experts for the technologies against Environmental criteria

Experts	*Rank Type*	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*T7*	*T8*	*T9*
E1	CR	3	1	1	1	2	1	1	2	1
	GR	[2.5,3.5]	[0.5,1.5]	[0.5,1.5]	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]	[0.5,1.5]	[1.5,2.5]	[0.5,1.5]
E2	CR	3	2	5	4	2	1	1	5	4 or 5
	GR	[2.5,3.5]	[1.5,2.5]	[4.5,5.5]	[3.5,4.5]	[1.5,2.5]	[0.5,1.5]	[0.5,1.5]	[4.5,5.5]	[3.5,5.5]
E3	CR	3	2	4	3	2	3	1	5	4
	GR	[2.5,3.5]	[1.5,2.5]	[3.5,4.5]	[2.5,3.5]	[1.5,2.5]	[2.5,3.5]	[0.5,1.5]	[4.5,5.5]	[3.5,4.5]
E4	CR	3	1	4	2	4	3	1	4	3
	GR	[2.5,3.5]	[0.5,1.5]	[3.5,4.5]	[1.5,2.5]	[3.5,4.5]	[2.5,3.5]	[0.5,1.5]	[3.5,4.5]	[2.5,3.5]
E5	CR	2	1	3	3	2	3	1	4	3 or 4
	GR	[1.5,2.5]	[0.5,1.5]	[2.5,3.5]	[2.5,3.5]	[1.5,2.5]	[2.5,3.5]	[0.5,1.5]	[3.5,4.5]	[2.5,4.5]
E6	CR	2	2	3	1	2	2	1	3	2
	GR	[1.5,2.5]	[1.5,2.5]	[2.5,3.5]	[0.5,1.5]	[1.5,2.5]	[1.5,2.5]	[0.5,1.5]	[2.5,3.5]	[1.5,2.5]
E7	CR	9	3	7	6	5	4	1	8	2
	GR	[8.5,9.5]	[2.5,3.5]	[6.5,7.5]	[5.5,6.5]	[4.5,5.5]	[3.5,4.5]	[0.5,1.5]	[7.5,8.5]	[1.5,2.5]
E8	CR	3	1	3	2	4	2	1	4	3
	GR	[3.5,4.5]	[0.5,1.5]	[3.5,4.5]	[1.5,2.5]	[3.5,4.5]	[1.5,2.5]	[0.5,1.5]	[3.5,4.5]	[3.5,4.5]
E9	CR	2	1	3	4	3	3	1	4	5
	GR	[1.5,2.5]	[0.5,1.5]	[3.5,4.5]	[3.5,4.5]	[3.5,4.5]	[3.5,4.5]	[0.5,1.5]	[3.5,4.5]	[4.5,5.5]
E10	CR	4	1	5	4	3	3	1	3	2
	GR	[3.5,4.5]	[0.5,1.5]	[4.5,5.5]	[3.5,4.5]	[3.5,4.5]	[3.5,4.5]	[0.5,1.5]	[3.5,4.5]	[1.5,2.5]

Table 8. Weights and ranking of criteria

Criteria	**Lower limit**	**Upper limit**	**Average weights**	**Rank**
Economy	0.2792	0.4557	0.3674	2
Social	0.1820	0.2232	0.2026	3
Environmental	0.3388	0.5211	0.4300	1

5. Conclusion and recommendations

Climate change is a global issue, and the agricultural sector is an integral part of it. Agriculture activities significantly influence the economy, society, and environment, which are the main indicator of sustainable development. Using low-carbon and sustainable agricultural technology can help mitigate the adverse effect on the environment and increase global food security. But selecting appropriate low-carbon and sustainable agricultural technology for the agricultural industry becomes a big problem. There are many MCDM methods in literature to help decision-makers, but several methods are not equipped to deal with uncertainty in information. Thus, this study employed the Grey Ordinal Priority Approach (OPA-G), a modern multi-attribute decision-making technique that will help decision-makers select the best possible alternatives/technologies for the agricultural industry.

To achieve sustainable development goals (SDGs), the contribution of the agriculture sector cannot be neglected. Implications of low-carbon and sustainable agricultural technology is an inevitable choice for government and policymakers in developed and developing countries. Despite the negative effects from the agriculture sector, it would be easier to mitigate climate change than any other sector. This study identified a number of well-known key low-carbon and sustainable agricultural technologies that have proven their usefulness for all agriculture activities in most countries and have the potential to be used. The implications of these technologies in the agriculture sector can help tackle global climate change and ensure global food security.

Table 9. Weights and ranking of technologies

Alternatives	Lower limit	Upper limit	Average weights	Rank
Integrated crop-livestock systems (T1)	0.1313	0.2100	0.1706	1
No-tillage (T2)	0.0979	0.1877	0.1428	2
Integrated crop-livestock-forest system (T3)	0.0971	0.1342	0.1156	5
Conservation agriculture (T4)	0.1007	0.1614	0.1310	4
Integrated Soil Fertility Management (T5)	0.0600	0.0808	0.0704	7
Agroforestry (T6)	0.0932	0.1157	0.1045	6
Carbon sequestration (T7)	0.1097	0.1596	0.1346	3
Crop diversification (T8)	0.0602	0.0788	0.0695	8
Soil and water conservation (T9)	0.0499	0.0720	0.0609	9

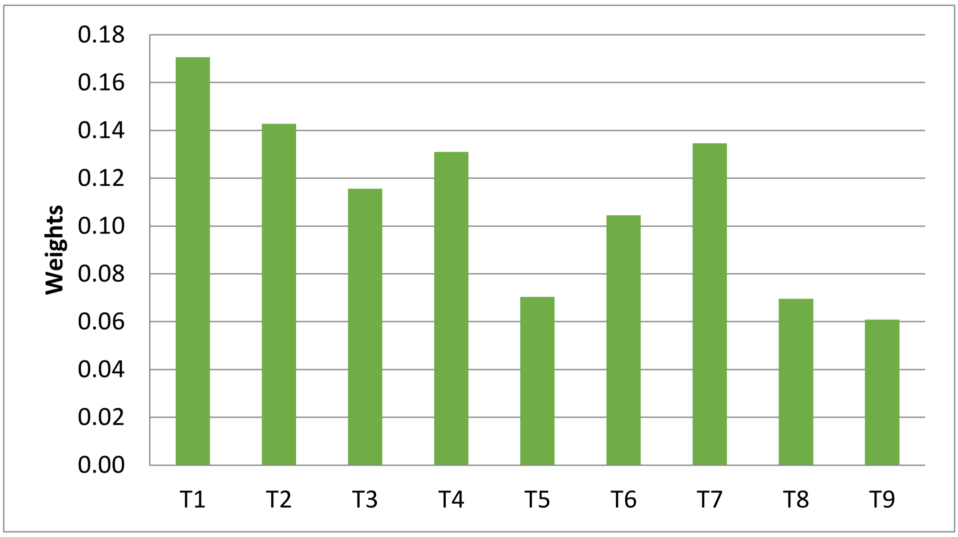

Figure 4. The ranking of technologies based on the OPA-G

Although the theory of the OPA-G model seems superior in many aspects when compared with the classical MCDM theories, it can further be improved. Identifying qualified experts for the data collection of different alternatives based on a sustainable approach has brought more research questions for this model. Experts' opinions are crucial for the decision-making process; experts' unfair or biased judgment can affect the final results. A standardized objective methodology to prioritize experts is needed. The development of a tool to predict the level of reliability can improve its effectiveness. The model should be applied to solve diverse problems to better understand its limitations and strengths in the future.

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Evaluating Site Selection Criteria for Marine Cultivation in North Lombok Regency of Indonesia through GADA model

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Abstract: Identifying the requirements for selecting water locations for marine cultivation requires identifying and objectively selecting cultivation locations. The study aims to identify site selection criteria to develop marine cultivation in Indonesia's North Lombok Regency, followed by their prioritization based on perceived significance. The selection criteria are through extensive review of literature, and are evaluated based on primary data. Grey Absolute Decision Analysis (GADA) model was used to evaluate the criteria. Comparative analysis with the Simple Additive Weighting (SAW) and TOPSIS methods confirmed the soundness of the results obtained through GADA. It was found that oceanographic conditions are most essential criterion for site selection for marine cultivation development. The results are important for marine cultivation businesses looking for suitable site in North Lombok Regency.

Keywords: Water location; marine cultivation; development; grey system theory; multiple criteria decision making

1. Introduction

Indonesia is located between the Australia-Asia continents, the Indian-Pacific Ocean, and is one of the world's emerging economies. Among its essential exports includes textile, rubber, and palm oil, among others. Indonesia is the world's second largest producer of fisheries after China (FAO, 2020). In 2018, the contribution of fisheries and fish industry to the Indonesian GDP was 2.7% (Statista, 2020). Therefore, the government's effort in implementing the Fishery Product Export Improvement Program is to develop marine cultivation. High productivity from aquaculture expects to take over capture fisheries production (Widodo, 2001) through resource optimization and the application of science (Meske & Vogt, 1985). The importance of aquaculture activities in increasing fishery products, such as restocking, stock enhancement, and farming biota is known through literature (Gimin, 2001). Cultivation is an activity that is most likely to be applied considering the high level of productivity, both the unity of organisms, land, and time.

North Lombok Regency (NLR) is one of Indonesia's coastal districts, with a coastline of about 125 km. The coastal and marine area has many caves, potential areas for aquatic cultivation (mariculture) development. According to Utojo and Mansyur (2007), the location can carry out the development of mariculture businesses such as coastal areas (bays) because they can protect from the influence of strong currents, large waves, strong winds, and free of pollution. Mariculture has a lively and bright prospect to be developed to increase coastal communities' income, raise local revenue, increase country foreign exchange, and avoid environmental damage (Junaidi *et al.*, 2018). Pearl shells, seaweed, lobster, and grouper are marine fishery commodities that are frequently exported, and these four commodities are primarily developed in North Lombok Regency (see Table 1). However, they are still on a small and simple scale. The demand and price of these commodities in the domestic and international markets continue to increase every year. It shows that marine cultivation is the right solution to reduce coral reef ecosystems' damage due to irresponsible fishing that recently often occurs in Northern Lombok.

The interaction between the culture biota and the outside environment is robust and almost no barrier. Based on the history of cultivation in various parts of the world, selecting the right location is essential in determining the feasibility of cultivation (Milne, 1979). Some non-conforming units can become profitable or even forces to abandon them after spending a fortune, even with technology ventures. Therefore, location selection is crucial for the success of cultivation (Sukandi, 2002; Muir & Kapetsky, 1998). Therefore, choosing the right and good criteria of the location is one of the determining factors for marine cultivation and the availability of seeds, feed, and guaranteed markets and prices (Affan, 2011). Species usually determine the determination of cultivation. However, the review of the availability of these factors is incomplete. Water quality, as one of them, will affect the determination of other supporting elements. Another essential consideration factor is the location's biographical parameters to be reviewed (physical, chemical, and biological, non-technical parameters, namely market, security, and human resources (Pillay, 1990; Milne, 1979). In cultivation development, a problem that often arises is improper environmental selection. Therefore, proper and detailed data are needed. However, the problem occurs is the placement of mariculture locations is predictive, so needs an accurate description criterion and avoiding non-supportive environmental influences (Radiarta *et al.*, 2005). Therefore, by extending the work by Junaidi *et al.* (2018) and Szuster and Albasri (2010), the current study identifies the site selection criteria for marine cultivation development in North Lombok Regency followed by its evaluation.

In the current study through exnsive review of literature some criteria will be identified for proper site for marine cultivation, and later using an emerging multi-criteria decision-making approach (MCDM), called Grey Absolute Decision Analysis (GADA) model, the criteria will be evaluted. The study will also use two other MCDM models for comparative analysis purpose. The study is organizes as follows: after introduction, the literature review is presented, which expects to provide an overview and essential points about the basics that are in line with the learning theme, namely overview of marine cultivation in Indonesian and North Lombok Regency. The criteria identification is also performed. In the third part, the methodological approach and models are discussed. The next part is regarding results and discussion where relative weights and rankings are obtained. In the last part, the conclusions and recommendations are presented for the readers.

2. Literature Review

2.1 Marine Cultivation Development in Indonesia

Mariculture is the cultivation of marine organisms for food and other products such as medicines, food additives, jewelry (for example, cultured pearls), nutraceuticals, and cosmetics, either in a natural marine environment or in terrestrial or aquatic cages, such as cages, ponds, or raceways. Seaweed, mollusks, shrimp, sea fish, and various other small species such as sea cucumbers and seahorses are among the multiple organisms currently cultivated around the world's coastlines. The fact is that the cultivation development location's determination is more based on feeling or trial and error (Hartoko & Helmi, 2004). Data or information about site suitability is essential to solving coastal use competition (Radiarta *et al.*, 2005). Proper management of aquatic resources expects appropriate suitability for each intended use of these resources. Therefore, packaging and arrangement are necessary (Zonneveld *et al.*, 1991). The development of mapping technology can determine the cultivation location (Budiyanto, 2005; Torres *et al.*, 1988). The technology application used to describe the site for the development of marine culture combined with the aquatic ecosystem's parameters.

Indonesia is the largest archipelago country globally with a manageable sea area of 5.8 million km2, a vast diversity of marine and fishery resources. The Maximum Sustainable Yield (MSY) potential in Indonesia's marine territory is 6.5 million tons each year, with the permitting amount can be caught 5.2 million tons each year (Decree of the Minister of Marine Affairs and Fisheries of the Republic of

Table 1. Marine Fisheries Production by kind of Fish, 2010-2016 in NLR (*Source*: TMAF, 2021)

Type of Fish	Production (Ton)						
	2010	2011	2012	2013	2014	2015	2016
Lizard Fish	291.40	-	126.00	101.10	107.70	115.50	414.50
Groupers	189.00	7.00	-	-	362.30	240.00	161.80
Emperarsd	-	-	541.10	-	-	-	-
Threadfin	189.00	313.20	2.60	430.30	408.80	400.00	298.90
Big Eyes	-	-	4.10	-	-	-	-
Yellow Tail	-	-	2.30	-	-	-	37.30
Sharde	2.20	7.00	-	-	-	-	-
Rays	2.20	457.81	-	4.30	4.30	-	-
Barracudas	-	-	-	-	-	-	3.60
Scard	1,457.60	991.50	-	1,490.70	1,419.30	1,525.50	1,140.90
Trevallises	1,165.40	693.40	637.10	14.00	11.80	12.80	603.90
Jacks	1.30	-	14.70	-	-	-	15.50
Rainbow Rumors	-	-	-	-	-	75.5	-
Flying Fish	-	-	-	-	-	1,175.00	-
Gar Fish	890.10	119.00	417.40	335.40	360.20	380.50	261.50
Anchivies	187.00	211.00	94.50	149.90	157.10	160.20	0.80
Fringascale	291.80	516.90	126.45	101.10	113.70	115.50	1,056.80
Indian Oil Sardinella	601.80	458.90	304.70	312.40	318.80	321.70	373.40
Indo Pacific	582.70	147.50	285.70	98.30	344.30	370.50	-
Narrow Barred	52.50	313.70	192.20	157.40	152.20	150.30	287.00
Hairtail	191.80	-	538.80	425.30	419.40	420.40	74.80
Skip Jack Tuna	659.70	756.70	-	-	-	-	9.20
Eastern Tuna	-	-	1,261.30	1,135.70	1,215.80	1,217.50	644.50
Other Fish	2.20	363.30	-	-	26.00	-	169.20
Other Shrimp	16.70	-	-	27.10	19.00	-	0.30
Cammond	189.00	-	21.20	19.20	19.00	19.75	168.90
Kuniran	-	-	-	430.30	408.30	416.40	130.80
Gurita	-	-	-	8.7	8.7	8.8	9.6
Kerapu Karang	-	-	-	365.6	357.7	-	-
Kerapu Bebek	-	-	-	5.1	4.6	0.24	-
Baronang	-	-	-	304.5	317.7	315.7	326.1
Rejung	-	-	-	4	3.9	-	-
Pari	-	-	-	3.1	4.3	3.5	-
Udang digol	-	-	-	8.2	8.7	-	-
Udang Krosok	-	-	-	8.1	8.8	-	-
Udang Karang	-	-	-	2.5	8.4	7.4	-
Total	6,963.40	5,386.91	4,569.52	5,942.30	6,571.80	7,452.69	6,189.30

Indonesia Number KEP. 45 / MEN / 2011 regarding Potential Estimation of Fish Resources in the Indonesian Fisheries Management Area). For aquaculture, its potential is seawater cultivation of 8.3 million hectares (consisting of 20% for fish cultivation, 10% for shellfish cultivation, 60% for seaweed cultivation, and 10% for others). Indonesia is among top producers of fisheries and and aquaculture production in the world consistently from several years (FAO, 2020). It explains enormous opportunities for Indonesian fisheries. If cultivation manages carefully and responsibly, it will become a sustainable activity and boost Indonesia's development capital in the present and future.

2.2 North Lombok Regency – Location and marine cultivation

The North Lombok Regency is very strategically located in the golden triangle area of a tourism destination, as shown in Figure 1. The sea transportation route with the Lombok Strait is used as an increasingly busy sea transportation route, from the middle east for fuel oil traffic and from Australia in metal minerals to the Asia Pacific. There are three island clusters known as Gili Matra (Meno,

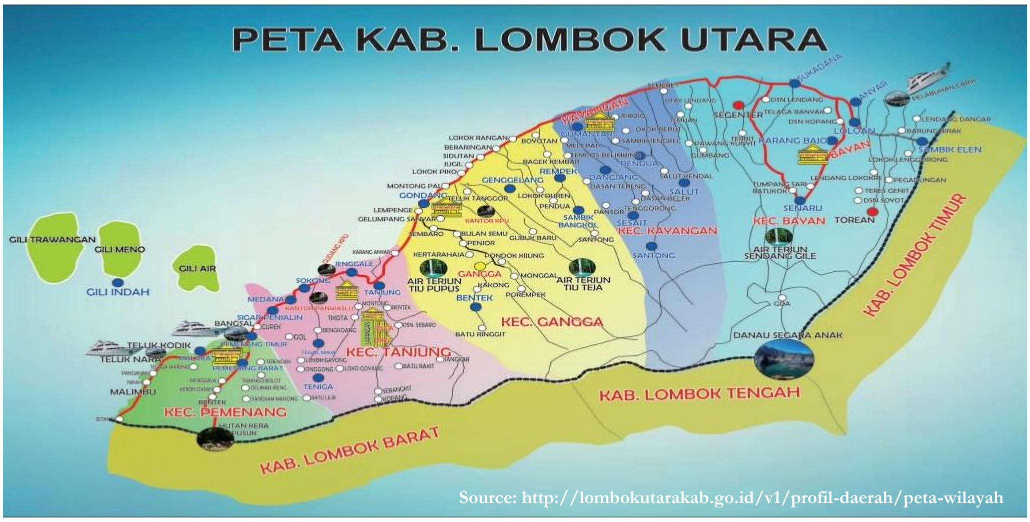

Figure 1. Map of the North Lombok Regency of Indonesia

Trawangan, and Air), marine tourism areas that are very well known to foreign nations as a beautiful and enchanting tourist destination. Besides being used as marine tourism, North Lombok coastal marine resources' potential is partly utilized as aquaculture and capture fisheries areas (Junaidi *et al.*, 2018).

Based on data from the Meteorology and Geophysics Agency, North Lombok Regency is classified as a tropical area with temperatures ranging from 23.1^{o}C, with the highest temperature occurring in July-August 32.9^{o}C and the lowest in April, namely 20.9^{o}C. Marine cultivation activities in North Lombok waters are already ongoing and are limited to several cultivation systems and commodities. The cultivation system used is floating nets and rafts, while the things cultivated include Tiger Grouper (Epinephelus Sp), Star Pomfret (Trachnotus Carolinus), Seaweed (Euchema Vottonii), and Pearl Shellfish (Pinctada Maxima).

North Lombok Regency (NLR) located in West Nusa Tenggara Province, with a position between 08^{o} 21 '42 "South Latitude and 116^{o} 09' 54" East Longitude, with boundaries areas as follows:

- North: Java Sea
- Westside: Lombok Strait and West Lombok Regency
- Southside: West Lombok Regency and Central Lombok Regency
- Eastside: East Lombok Regency

Tanjung is the capital of North Lombok Regency, which is also the center of Government. North Lombok Regency has a land area of 809.53 km^2 consisting of particular regions (protected forests, wildlife areas, etc.) covering an area of 361.86 km^2 (44.30%) and the remaining flat land for agricultural land, etc. covering 447.67 km^2 (55.30 %). The size of North Lombok waters is 594.71 km^2 with a beach length of 127 km. Administratively, North Lombok Regency is divided into 5 Districts, 33 Villages and 371 Hamlets, of which Bayan District has the largest area with a land area of 329.10 m^2 (40.66%) and the smallest is Pemenang District with a land area of 81.09 km^2 (10.01%), as shown in Table 2.

North Lombok Regency (NLR) is an important area for marine curltivation in Indonesia. The fishery in several areas along the coast of North Lombok Regency (NLR) has become the sub-sector of residents' choice to depend on their livelihoods. Most of the fishermen in North Lombok Regency are fishermen who catch fish in the sea, and only a small portion cultivate freshwater fish (flying fish and

Table 2. The Area of North Lombok Regency (Detailed by District)

No.	Sub-District	Total Area					
		Mainland		Sea		Total	
		km^2	Percentage	km^2	Percentage	km^2	Percentage
1	Pemenang	81.09	10.01%	*	*	81.09	5.77%
2	Tanjung	115.64	14.28%	302.26	50.82%	417.90	29.76%
3	Gangga	157.35	19.44%	100.33	16.87%	257.68	18.35%
4	Kayangan	126.35	15.61%	*	*	126.35	9.00%
5	Bayan	329.10	40.66%	192.12	32.30%	521.22	37.12%
	Total	809.53	100.00%	594.71	100.00%	1,404.24	100%

selar fish commonly caught). Production of tembang and selar fish in 2014 was 1,490.7 tons and 903.9 tons, respectively. Meanwhile, the most popular type of freshwater fish is tilapia. Tilapia production in 2014 reached 14.5 tons. In Table 1, the marine fisheries production is summarized for the region.

2.3 Identification of Criteria for Marine Cultivation

In this section, based on the literature, site selection criteria are identified. The result of this effort is shown in Table 3. In the table, C represents manin criteria and SC represent sub-criteria. The first criterion is the biophysical parameters. It is the first point and the most critical factor in determining the cultivation location because development for mariculture efforts does not escape the supporting elements of nature, the situation, and natural conditions. Environmental factors also one of the support that can't be left, namely humans who work in cultivation, facilities, and the help from the surrounding environment in the cultivation process. Ecological factors also support marine cultivation, which promotes the preservation of the local marine ecosystem.

Table 3. The Criteria and Sub-Criteria for Marine Cultivation

	Criteria (and Sub-Criteria)	**Description**	**Literature**
C1	*BIOPHYSICAL PARAMETERS*		FAO (2000; 1989)
MC1	Oceanographic conditions	-Tidal: feasibility testing in cultivation development. - Seabed conditions: plays an essential role in the ecosystem biota.	Szuster and Albasri (2010)
MC2	Water quality	- Water PH: an overview of the appropriate marine commodities. - Salinity: ability to penetrate light into the waters/photosynthesis process. - Dissolved oxygen conditions - Water temperature conditions - Water chlorophyll data: determination of primary productivity.	Szuster and Albasri (2010)
C2	*ENVIRONMENTAL FACTORS*		Zonneveld *et al.* (1991)
MC3	Location suitability	The location chosen is the one that is easiest to reach. With the cultivation location, which is relatively close to the household where it lives, it will be easier to maintain.	Zonneveld *et al.* (1991)
MC4	Availability of factor production and support facilities	Without factor production, such as humans and supporting facilities, this marine cultivation will not work. The main factor besides nature is humans themselves, who are engaged in cultivation.	Zonneveld *et al.* (1991)
MC5	Public perception and participation of the environment	A lively and supportive public view is needed for marine cultivation otherwise it will be difficult in the development process without residents' support.	Zonneveld *et al.* (1991)
C3	*ECOLOGICAL FACTORS*		Munasinghe (2002)
MC6	Use of floating net cage system	The development of this method can not separate from the direction of environmentally friendly cultivation because the issue of fish farming, which is identical to pollution, is a very compassionate matter. Therefore, both cultivation technology and materials and equipment used must have specific standards by environmentally friendly criteria.	Charles (2001)
MC7	Preservation of the form and function of natural ecosystems	Cultivation must be accompanied by conservation to preserve and sustain the cultivation ecosystem in the long term.	Charles (2001)

3. Research Methodology

3.1 Data Collection

In this study, the primary data was collected through an online questionnaire, which was sent to several relevant respondents. The questionnaire was developed on *SurveyMonkey* and shared with the potential respondents. Twelve people filled the questionnaire correctly, and their data was used for analysis through three models, discussion of which is presented in the succeeding section. The copy of the questionnaire can be obtained from the author on a reasonable request.

3.2 Data analysis techniques

3.2.1 Grey Absolute Decision Analysis. Grey System Theory was proposed in 1982 by Professor Deng Julong and is a powerful tool for processing uncertain information (Du *et al.*, 2021; Deng, 1982). Liu's Absolute Grey Relation Analysis (AGRA) is one of the essential parts of grey system theory (Liu, Yang & Forrest, 2017; Javed & Liu, 2019). The grey system here is assumed to be a system where some information is known, and some information is unknown (Fahim *et al.*, 2021; Javed *et al.*, 2020a). The theory is valuable when data is small, and data distribution is not a matter of concern (Javed *et al.*, 2020b; Mahmoudi *et al.*, 2020a). The theory allows us to view systems and data in white-grey-black spectrum, where data uncertainty is always in the middle, which refers to somewhere in the grey area (Javed *et al.*, 2021; Mahmoudi *et al.*, 2019). The grey analysis then forms a series of clear statements regarding the system's solution, unclear and incomplete data (Mahmoudi *et al.*, 2020b). Therefore, this system will provide various available solutions. The grey analysis may not produce the best solutions but it offers good solutions, the right solution to real-world problems.

Multiple criteria decision making (MCDM) is an essential part of operations research and has its application in various fields (Mahmoudi *et al.*, 2020c). Grey Absolute Decision Analysis (GADA) method is one of the new developments in MCDM, and was proposed by Javed *et al.* (2020a) by fusing the advantages of weighted geometric mean and Liu's absolute grey relational analysis. The GADA weights represent the relative weight of alternatives against a set of criteria. The key advantages of GADA lies in its simplicity and lower computation cost (Ikram *et al.*, 2021). The model, in its simplest form, can be represented by the following formulas,

$$\grave{R}_j = \frac{\grave{r}_j}{\sum_{j=1}^{S} \grave{r}_j} \qquad \grave{\grave{R}}_j = \frac{\grave{\grave{r}}_j}{\sum_{j=1}^{S} \grave{\grave{r}}_j}$$

$$\grave{r}_j = \left(\prod_{j=1}^{S} r_j^{\alpha_i} \right)^{1/\sum_{i=1}^{N} \alpha_i} \qquad \grave{\grave{r}}_j = \left(\prod_{j=1}^{S} \grave{r}_j^{\delta(k)} \right)^{1/\sum_{k=1}^{M} \delta(k)}$$

where, $\alpha_i = \frac{1}{N}(\varepsilon_{i1} + \varepsilon_{i2} \ldots + \varepsilon_{iN})$, and $\grave{r}_j$ and $\grave{\grave{r}}_j$ represent GADA Indexes and $\grave{R}_j$ and $\grave{\grave{R}}_j$ represent GADA weights. Meanwhile, If the zero-starting point images of criteria Y_i and Y_j are $Y_i^0 = (y_i^0(1), y_i^0(2), \ldots, y_i^0(n))$ and $Y_j^0 = (y_j^0(1), y_j^0(2), \ldots, y_j^0(n))$ then the absolute grey relational grade is given by

$$\varepsilon_{ij} = \frac{1 + |s_i| + |s_j|}{1 + |s_i| + |s_j| + |s_i - s_j|}$$

where,

$$|s_i| = \left| \sum_{k=2}^{n-1} y_i^0(k) + \frac{1}{2} y_i^0(n) \right|, \; |s_j| = \left| \sum_{k=2}^{n-1} y_j^0(k) + \frac{1}{2} y_j^0(n) \right|$$

$$|s_i - s_j| = \left| \sum_{k=2}^{n-1} (y_i^0(k) - y_j^0(k)) + \frac{1}{2}(y_i^0(n) - y_j^0(n)) \right|$$

For further information and detailed computational steps governing the GADA model and Absolute Grey Relational Analysis, Javed *et al.* (2020a) and Liu *et al.* (2017) can be consulted, respectively.

Table 4. The Response Sheet and Aggregation

	MC1	MC2	MC3	MC4	MC5	MC6	MC7
R1	5	5	4	4	3	4	5
R2	5	5	4	4	4	4	4
R3	5	4	4	3	4	4	5
R4	4	4	4	4	4	4	5
R5	3	3	4	2	3	5	3
R6	5	5	4	4	4	4	4
R7	5	4	4	4	4	5	5
R8	4	4	4	5	5	4	4
R9	5	5	4	4	4	5	5
R10	5	5	5	5	5	5	5
R11	5	4	5	4	4	4	3
R12	4	3	2	3	3	2	2
GM	4.53	4.18	3.92	3.74	3.86	4.07	4.02

Table 5. Estimating α_i and $\sqrt{\alpha_i(\mathrm{k})}$

$\boldsymbol{\varepsilon}$	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	$\boldsymbol{\alpha_i}$	$\sqrt{\boldsymbol{\alpha_i(k)}}$
R1	1.000	1.000	0.923	0.636	0.727	1.000	0.909	0.727	0.818	0.546	0.923	0.790	0.833	0.913
R2	1.000	1.000	0.923	0.636	0.727	1.000	0.909	0.727	0.818	0.546	0.923	0.790	0.833	0.913
R3	0.923	0.923	1.000	0.615	0.692	0.923	0.846	0.692	0.769	0.539	1.000	0.842	0.814	0.902
R4	0.636	0.636	0.615	1.000	0.800	0.636	0.667	0.800	0.714	0.667	0.615	0.579	0.697	0.835
R5	0.727	0.727	0.692	0.800	1.000	0.727	0.778	1.000	0.857	0.600	0.692	0.632	0.769	0.877
R6	1.000	1.000	0.923	0.636	0.727	1.000	0.909	0.727	0.818	0.546	0.923	0.790	0.833	0.913
R7	0.909	0.909	0.846	0.667	0.778	0.909	1.000	0.778	0.889	0.556	0.846	0.737	0.819	0.905
R8	0.727	0.727	0.692	0.800	1.000	0.727	0.778	1.000	0.857	0.600	0.692	0.632	0.769	0.877
R9	0.818	0.818	0.769	0.714	0.857	0.818	0.889	0.857	1.000	0.571	0.769	0.684	0.797	0.893
R10	0.546	0.546	0.539	0.667	0.600	0.546	0.556	0.600	0.571	1.000	0.539	0.526	0.603	0.776
R11	0.923	0.923	1.000	0.615	0.692	0.923	0.846	0.692	0.769	0.539	1.000	0.842	0.814	0.902
R12	0.790	0.790	0.842	0.579	0.632	0.790	0.737	0.632	0.684	0.526	0.842	1.000	0.737	0.858

Table 6. Rankings of the site selection criteria

	MC1	MC2	MC3	MC4	MC5	MC6	MC7
$\tilde{r}$	4.5471	4.1920	3.9173	3.7212	3.8456	4.0675	4.0224
$\tilde{R}$	0.2776	0.2560	0.2392	0.2272	0.2348	0.2484	0.2456
Ranking	1	2	5	7	6	3	4

Table 7. Comparative Analysis of GADA with SAW and TOPSIS

Site Selection Criteria	GADA		SAW		TOPSIS	
	Weight	*Rank*	*Weight*	*Rank*	*Weight*	*Rank*
MC1: Oceanographic conditions	0.2776	1	0.2246	1	*N/A*	1
MC2: Water quality	0.2560	2	0.2082	2	*N/A*	3
MC3: Location suitability	0.2392	5	0.1960	5	*N/A*	5
MC4: Availability of factor production and support facilities	0.2272	7	0.1878	7	*N/A*	7
MC5: Public perception and participation of the cultivation	0.2348	6	0.1919	6	*N/A*	6
MC6: Use of floating net cage system	0.2484	3	0.2041	4	*N/A*	2
MC7: Preservation of the form and function of natural ecosystems	0.2456	4	0.2041	3	*N/A*	4
**N/A*: Not Applicable as TOPSIS cannot estimate weights						

3.2.2 Simple Additive Weighting. Simple Additive Weighting (SAW) is also known as the weighted addition method. The SAW method's basic concept is to discover the weighted sum of each alternative's performance ratings on all attributes (Simanaviciene & Ustinovichius, 2010; Fishburn, 1967). The SAW method requires a decision matrix normalization process to a scale comparable to all existing alternative ratings. This method is the most well-known and most widely used method of dealing with MCDM problems. This method requires helps determine the weight of each alternative based on the weights. The other options' total score obtains by adding up all multiplication results among scale and weight for each feature. The computational steps of SAW as reported in Afshari *et al.* (2010) were used in the current study.

3.2.3 TOPSIS. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was proposed in the 1980s by K. Yoon in his PhD dissertation (Yoon, 1980; Hwang & Yoon, 1981). It is one of the most influential MCDM methods. TOPSIS ranks the alternatives based on their distance from positive (best) and negative (worst) ideal alternatives (Zare *et al.*, 2018). TOPSIS has several benefits e.g., simplicity, rational, comprehensibility, reasonable computational cost and capability to produce relative performance of alternatives using simple mathematics (Ikram *et al.*, 2020). Also it has an appropriate performance when a decision matrix instead of a pairwise comparison matrix is available to data analyst (Mahmoudi *et al.*, 2020c). The computational steps of TOPSIS as reported in Hwang and Yoon (1981) were used in the current study.

4. Data and results

4.1 Site Selection through GADA

This study is group decision-making to determine the site selection of marine cultivation, which is proven and analyzed using the GADA method. We have seven alternatives / possible criteria in determining the site selection of marine cultivation (MC: seven criteria in determining the location of cultivation) and 12 independent decision-makers (R: expert). Since the study's objective is to rank the criteria therefore the experts' opinions about their importance was sought using 5-point Likert scale, as shown in Table 4, where "1" deputizes the lowest score, "5" deputizes the highest score. All have higher the better characteristic. Thus, concerning MC, score "1" is the worst, and score "5" is the best one. The execution of the GADA method is shown in Tables 5 and 6.

4.2 Comparative Analysis with SAW and TOPSIS

The comparative analysis of the results obtained through GADA method are compared with those of SAW and TOPSIS methods in Table 7. Figure 2 illustrates the comparison of the rankings of the three methods. The comparative analysis reveals that their results are comparable though not entirely. However, according to all methods the oceanographic conditions (MC1) is the top scorer, the most important criteria for site selection for marine cultivation.

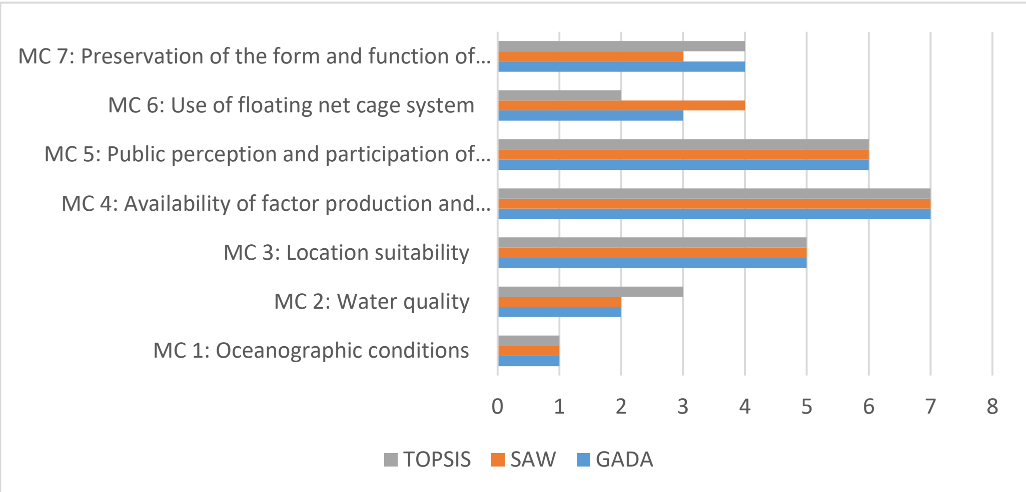

Figure 2. Rankings obtained through GADA, SAW, and TOPSIS

According to the GADA method, Oceanographic conditions (MC1) gets the highest order relative weight means selected to be the most critical criterion. It followed by Water quality (MC2), Use of floating net cage system (MC6), Preservation of the form and function of natural ecosystems (MC7), Location suitability (MC3), Public perception and participation of the cultivation (MC5), Availability of factor production and support facilities (MC4). The results from GADA were mostly comparable with those of SAW and TOPSIS except for the second, sixth and seventh criteria, as can be seen from Table 7. For the Water quality (MC2), GADA and SAW ranked it second while TOPSIS ranked it third most important criteria for site selection, while for Preservation of the form and function of natural ecosystems (MC7), GADA and TOPSIS categorized it as fourth while SAW ranked it as third. For Use of floating net cage system (MC6), the methods failed to achieve consensus and ensemble ranking (Mohammadi & Rezaei, 2020) may be needed. Overall, the results are realistic and convincing.

5. Conclusion and recommendations

Cultivation activities are one of the popular activities in Indonesia. It is undeniable that Indonesia's natural wealth makes it one of the main factors in implementing a cultivation system to optimize natural resources and improve human resources. It provides a positive boost to Indonesia's economic development. Marine cultivation often in all countries with extensive water areas, one of which is Indonesia, an archipelago country. This activity certainly positively impacts the land itself; high productivity can cultivate an export commodity to countries in need and meet domestic market demand. However, in determining any cultivation, determining or supporting factors are needed in the activity. Here, the author focuses on marine cultivation applied in North Lombok, which is already known for its marine wealth and extraordinary ecosystems and opportunities.

Cultivation activities as one of Indonesia's facilities and infrastructure in developing and optimizing natural products, of course, require a thorough review before being carried out so that the sustainability of cultivation is sustainable. With the multi-criteria decision-making model applied to 12 related people and analysed using the GADA, SAW and TOPSIS systems, the author has researched and is responsible for the resulting data that is not engineered and original. The results obtained are likely to benefit decision-makers and parties involved in determining marine culture's location. The determination of marine culture location based on the results and discussion shows that oceanographic conditions are the most critical factor in determining cultivation location. The criteria for each alternative decision cannot compare with one another; all have the same importance. The evaluation results expect to provide convenience for people who need a determinant analysis of marine cultivation locations before making decisions, such as business companies related to aquatic cultivation or domestic or foreign investors who wish to invest in marine cultivation in Indonesia in the future.

The limitation of the study lies in the limited number of respondents (experts) so that in the future, it is necessary to increase the number of decision-makers to improve the quality and validity of the data—the results obtained from the analysis of three different methods resulted in significant data similarities. Therefore, the author recommends the GADA method as a convenient and straightforward method for researchers based on Multi-Criteria Decision Making. The study confirms that the GADA method's advantage in analysing complex problems through simple steps, and ability to handle small samples, make it a promising approach to handle MCDM problems. In future, the GADA method can be extended to make its results more optimum, especially in linguistic environment.

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Demand Forecasting of Toyota Avanza Cars in Indonesia: Grey Systems Approach

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Abstract: Toyota Avanza car is a popular four-wheeler among Indonesia middle-class customers. The current study aims to forecast the demand for Toyota Avanza cars in Indonesia in the next six years using the grey forecasting model EGM (1,1, α, θ). The comparative analysis of the results obtained from the grey model with those of Linear Regression, Exponential Regression, and Exponential Triple Smoothing techniques revealed the superiority of the grey model as it produced most accurate forecasts. The accuracy was measured through the Mean Absolute Percentage Error. The results revealed, the car sales are likely to decline in the future. Although forecasts are never completely accurate, forecasting can provide a reference for developing strategy to meet future demand. The results are important for Toyota Avanza car manufacturers in Indonesia.

Keywords: Sales forecast; Toyota Avanza; automobile demand; Indonesia; grey forecasting

1. Introduction

In early 2017, Toyota had controlled nearly 40% of Indonesia's total market share of four-wheeled vehicles. That means 4 out of 10 new cars sold in Indonesia each year are Toyota (Chalil, 2017: 5). Who is the person in Indonesia who does not know the Toyota Avanza? Many Indonesian families choose this car and almost always dominate sales in the Low Multi-Purpose Vehicle (LMPV) class. The Avanza was first introduced at the 2003 Gaikindo Auto Show to enter the Indonesian market as a new choice as a family car for Indonesians (Rio, 2019). Avanza in the Indonesian MPV market continues to show its success. Even now, the Toyota Avanza is the most MPV category passenger vehicle on Indonesian roads. Sales data from the Association of Indonesian Automotive Industries (Gaikindo) also shows the MPV of the Avanza brand number one every month (DetikOto, 2010). Many factors cause the market for the Toyota Avanza to fluctuate, which has a wide and varied market share, ranging from low prices to stylish ones at higher prices (Soerjopranoto, 2017).

On the other hand, people consider several things when buying a product. The consideration is according to the needs or based on his wishes. Price is also another consideration. Toyota Avanza is a car that families love in Indonesia with all its capabilities and a relatively affordable price. There were no rivals at that time when he walked alone for years, becoming an idol and market leader in Indonesia at the beginning of its launch in 2003, and from there, the Toyota Avanza continues to plant the image of a million cars. The Toyota Avanza has been working for 17 years in Indonesia to become the best-selling low multipurpose vehicle (LMPV) in Indonesia.

Even though the Toyota Avanza is the best-selling car for dozens of years in Indonesia, now the car had to experience a decline in sales due to the outbreak of the COVID-19 pandemic, which has weakened the Indonesian currency. When sales were sluggish due to this outbreak, the price of Toyota Avanza cars went up. Marketing Director of PT Toyota Astra Motor has confirmed this price hike (Jimmi, 2020). The production cost factor and the rupiah exchange rate against the US dollar are the reasons for the increase in car prices. His side has also thought about this price increase so as not to cause demand to decrease drastically. However, he did estimate that there would be an impact on the sales figures from increased car prices. Events that occur in the next six years, from 2020 to 2025, will greatly affect sales, which have fluctuated compared to sales in the last few years. Thus, there is a dire need to have accurate forecasts of the demand for these cars.

PT Toyota- Astra Motor (TAM) and PT Toyota Motor Manufacturing Indonesia (TMMI) are key stakeholders in the Toyota market. TMMIN focuses as a vehicle manufacturing company and vehicle components as well as an exporter of the whole, semi-finished vehicles, vehicle components including engines and production aids. Meanwhile, TAM focuses as a distributor of Toyota branded vehicles and after-sales service. In Indonesia, Toyota is represented by two subsidiaries, namely PT Toyota Motor Manufacturing Indonesia (TMMIN) and PT Toyota Astra Motor (TAM). As a subsidiary of Toyota Motor Corporation headquartered in Japan, TMMIN acts as a manufacturer and exporter of Toyota products and parts, while TAM acts as an agent brand holder, importer and distributor of Toyota products. PT Toyota Motor Manufacturing Indonesia (TMMIN) for more than four decades, TMMIN has played an important role in developing the automotive industry in Indonesia and job opportunities for its supporting industries. Currently, TMMIN has five factories operating in Sunter and Karawang, Indonesia (PT, 2014). Data from these stakeholders can be a rich resource for forecasting demand for Toyota vehicles.

From Figure 1 (data from Gaikindo), it is clear that a continuous decline occurred every year starting from 2013 with 213,458 units until it decreased in 2018 with total sales of 82,167 units. However, in 2019 the number of sales increased by 4,207, making sales in 2019 to 86,374 units. Although the Toyota Avanza continued to decline in 2019 could be a good sign for the company because of an increase. Executive General Manager of TAM, Fransiscus Soerjopranoto, said that many things affect sales figures' ups and downs (wholesale and retail sales). "Basically, the ups and downs of the wholesale or retail sales figure are influenced by many things, both the market condition itself and the availability of units at the dealer"(Budiman, 2018). Therefore, forecatsing accurate demand for the Toyota Avanza is important for the industry.

The rest of the study is organized as follows. Section two presents the review of the literature. Section three is about research methodology. Section four presents the results and discussion. Section five concludes the study.

2. Literature Review

2.1 Toyota Avanza Cars in Indonesia

For the upper-middle class in Indonesia, a car is a means of personal transportation needed to carry out their daily activities. Cars are used to go to work, school, market, meet relatives, on vacation, or even transport goods. Cars help speed up daily activities, although some people buy cars to increase their prestige in society, and not as a matter of necessity (Riyanto, 2005). In Indonesia, the total number of motorized vehicles has touched hundreds of millions of units, reaching 146,858,759 units. Most of them are dominated by motorbikes with more than 100 million units, namely 120,101,047 units and 16,440,987 units cars, according to data from the Central Statistics Agency (BPS) in 2018. According to data from the Association of Indonesian Automotive Industries (Gaikindo), in 2019, Indonesia has paved 1,043,017 new cars. That figure is retail sales (from dealers to consumers), including sales of commercial vehicles such as trucks and buses (Rahardiansyah, 2020).

At the end of 2003, the Indonesian marketing world was shocked by Toyota's latest product, when the Toyota Avanza brand was launched (Hermawan, 2004). Since it was first introduced to the public in December 2003, the Toyota Avanza was immediately greeted with great enthusiasm by the Indonesian people, where more than 43,000 Avanza units were sold in its inaugural year. With a reliable and robust DNA 7-Seater Multipurpose Vehicle (MPV), at the age of 16, Avanza is increasingly trusted by the public to become the best-selling MPV in Indonesia with more than 1.8 million subscribers. In 2019, Avanza sales figures grew by 6.9% compared to the previous year, amidst a decline in market

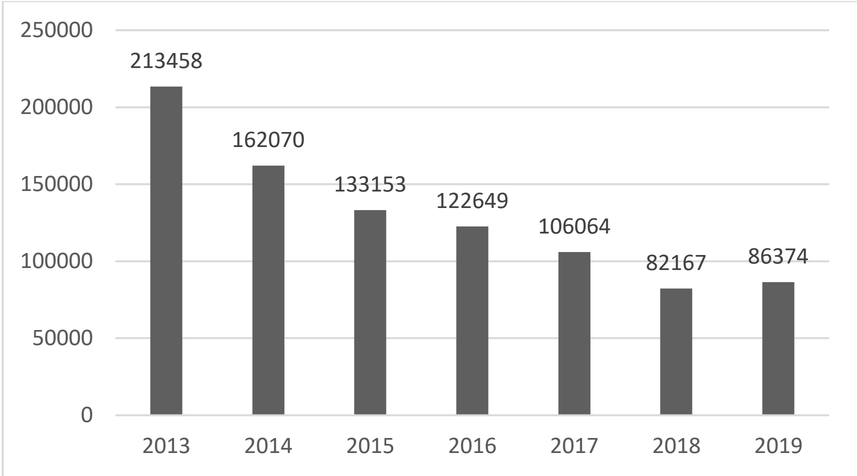

Figure 1. Toyota Avanza car sales from 2013 to 2019

demand of 11.1% in the Low MPV segment. This data proves that Avanza remains an option because it can meet the expectations and needs of the Indonesian (Sikker, 2019).

It seems that the Toyota Avanza is not only in demand by Indonesians. Many people in other countries are also quite interested in this million people's MPV car. The tastes and choices of the neighbouring countries such as the Philippines, Myanmar, Vietnam, Thailand, Brunei Darussalam, Laos, Singapore and Malaysia are comparable to those of Indonesia. That is why these ASEAN countries are listed in the Avanza export data. Not to forget that outside of ASEAN, there are South Africa, Bermuda, West Africa, Madagascar, Pakistan, Srilanka, Saudi Arabia, Peru, Bangladesh, Lebanon, Qatar, Kuwait, Oman, Yemen, Honduras, Guatemala, and several other countries that also import Toyota Avanza (Rayanti, 2018).

The Toyota brand still dominates the top five Indonesian assembled cars that sell overseas. The Indonesian Automotive Industry Association's databases (Gaikindo) confirm this fact. Avanza sits in second place under the big Toyota Fortuner. From January to November 2018, 32,536 Toyota Avanza units were sent from Indonesia to overseas (Rayanti, 2018). From this data, it can be seen that the Toyota Avanza is not only popular and well-known in Indonesia, but also to various countries around the world who are interested in this car.

2.2 Demand Forecasting of Automobiles in Indonesia

Demand theory explains the habitude of buyer demand for a commodity (goods and services) and explains the relationship between the number demanded and the price and the formation of the demand curve (Sugiarto *et al.*, 2007). Demand is the various quantities of goods demanded by consumers at various price levels in a certain period (Pracoyo & Pracoyo, 2006: 29). Many factors influence consumer demand for an item, including price, income, taste, season, population, etc. Thus, it can be concluded that demand is the desire of buyers or consumers accompanied by the availability of goods and buyers' ability to buy goods or services at a specific price and time.

Forecasting is an attempt to predict future conditions through testing conditions in the past. The essence of forecasting is predicting future events based on past patterns; and using policies on projections with past patterns. Simply put, forecasting is the art and science of predicting future events. This can be done by involving past data collection and placing it into the future with a mathematical model (Prasetya & Lukiastuti, 2009). Demand forecasting is the projection of demand for a company's products or services that control production, capacity and scheduling systems and become input for financial planning, marketing and human resources (Prasetya & Lukiastuti, 2009). This prediction predicts the demand for cars by the Toyota Avanza Cars company in Indonesia at each time horizon by using time series data for sales of Toyota Avanza Cars in Indonesia from 2013-2019.

Trend analysis makes a general trend model for time series data and allows forecast calculations for future data periods. Several models are commonly used for trend analysis: the linear trend model, the quadratic trend model, the exponential growth trend model, and the S-Curve model (Rusli, 2014). In this study, the type of trend used is the Linear Trend model, or it can be called the linear least square

Table 1. Summary of literature on automobile forecasts

Year	Region of focus	Automobile type	Description	Model	Literature
1981	Japan	All automobile type	The study outlines the use of linear and nonlinear models in forecasting net car sales of the Japanese automotive industry.	Linear and nonlinear models and GMDH method.	Nishikawa and Shimizu (1981)
1985	USA	All automobile type	Describes a simulation model for the U.S. automobile market.	Disaggregate Choice models.	Berkovec (1985)
1997	Spain	All automobile type	The study investigates the forecasting ability of unobserved component models.	ARIMA models.	Ferrer *et al.* (1997)
2009	USA	All Automobile Type (Domestics and International)	The study forecasted the automobile sales using the SPSS statistical package.	Regression models.	Shahabuddin (2009)
2010	Palestine	All automobile type	The study forecasted automobile demand for the economies in transition.	Simultaneous-equation model.	Abu-Eisheh and Mannering (2010)
2012	Solo, Indonesia	Mitshubisi Colt T120	To see the demand forecast for Mitsubishi Colt T120 cars at PT Sun Star Solo in April 2012.	Single Moving Average, Weight Moving Average, and Exponential Smoothing.	Putri (2012)
2018	Indonesia	Mitshubisi Xpander	To forecast the demand of the automobile.	Moving Average, Exponential Smoothing and Trend Analysis.	Iwan *et al.* (2018)
2020	Japan	Sedans and Commercial Cars	The study focused on automobile demand forecasting. Two models were built to predict the demand of two classes of cars in Japan every month for up to 36 months in advance.	FMC and MMC.	Kato (2020)
2021	Indonesia	Toyota Avanza	To forecast the demand (sales) of Toyota Avanza in Indonesia.	Grey Forecasting model EGM (1,1,α,θ).	The current study

trend because it is very suitable and easily understood by researchers. The linear trend is a long-term, slow movement and tends to go in one direction, towards an up or down direction (Rusli, 2014). Table 1 summarizes the literature on forecasting of automobiles.

3. Research Methodology

3.1 Data Collection

In this study, the type of forecasting used is demand forecasting using secondary data. Secondary data is a historical data structure regarding the variables that have been previously collected and compiled by other parties (Hermawan, 2005). The data was collected from Gaikindo (www.gaikindo.or.id/indonesian-automobile-industry-data) from the 2013 - 2019 period. It contains sales data from PT Toyota-Astra Motor (TAM) and PT Toyota Motor Manufacturing Indonesia (TMMI).

3.2 Forecasting techniques

The study used a Grey Forecasting model, and then comparative analysis with three popular statistical models was performed using the Mean Absolute Percentage Error.

3.2.1 Even Grey Model (1, 1, α, θ). Grey system theory is a scientific theory first put forward by the Chinese scientist Julong Deng in the 1980s (Aydemir, 2020), and one of the strengths of this theory and its grey forecasting models is the ability to perform well using small samples and information, which can be incomplete (Javed *et al.*, 2020a; Mahmoudi *et al.*, 2020). Furthermore, the grey forecasting model is an intelligent time series prediction technique that can reliably forecast future patterns. Grey forecast allows you to get useful information about the future from small data, which can be up to four and can be used for short and long-term forecasts (Javed *et al.*, 2020b). The term GM(1,1) indicates one variable and first-order differential (Lin *et al.*, 2011). Even Grey Model (1, 1, α, θ) is a reliable forecasting model proposed by Javed *et al.* (2020c). Let the sequence of actual data is $X^{(0)} = \left(x^{(0)}(1), x^{(0)}(2), \dots x^{(0)}(n)\right)$. And the sequence of conformable fractional accumulated data of $X^{(0)}$ is $X^{(\alpha)} = \left(x^{(\alpha)}(1), x^{(\alpha)}(2), \dots x^{(\alpha)}(n)\right)$ where, $x^{(\alpha)}(k) = \sum_{i=1}^{k}\left(\frac{x^{(0)}(i)}{i^{1-\alpha}}\right), k = 1,2,\dots,n$, where α values lie between 0 and 1.

The time response equation of the model is given by,

$$\hat{x}^{(0)}(k) = k^{1-\alpha}\left(\hat{x}^{(\alpha)}(k) - \hat{x}^{(\alpha)}(k-1)\right), k = 1,2,\dots,n$$

$$\hat{x}^{(0)}(k) = k^{1-\alpha}(1 - e^{\alpha})\left(x^{(0)}(1) - \frac{b}{a}\right)e^{-a(k-1)},\ k = 1,2,\dots,n$$

The parameters a and b can be calculated through the least-squares method, such as

$$[a, b]^T = [B^T B]^{-1} B^T Y$$

where, $B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix}$ and $Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}$

The complete details about the model and its parameters can be found in Javed *et al.* (2020c).

3.2.2 Linear Regression. The phenomenon of regression analysis aims to determine the regularity of phenomena development (Rusov *et al.*, 2017). Based on this regularity, regression analysis can predict the future direction of phenomena. Regression models imply a class of stochastic models represented by equations in which the dependent variable is expressed as a linear or non-linear function of the independent variable (Flood, 2020). A linear regression model defines the relationship between the dependent and independent variables in a straight line. The Linear Regression formula is as follows:

$$Y = a + bX$$

In this formula, a is the value of *Y* when *X* is equal to 0. The slope of the regression line is b, which indicates the change in *Y* for each unit of change in *X*. The current study used the following formula for demand forecasting in MS Excel,

Y = -23856**year* + 220091

3.2.3 Exponential Regression. A non-linear regression method is a form of relationship or function in which the independent variable *X* and/or the dependent variable *Y* can function as a factor or variable with a certain rank. Besides, the independent variable *X* and/or the dependent variable *Y* can function as a denominator (fractional function), and the variable *X* and/or the variable *Y* can function as a power exponential function = power function. One of the models of non-linear regression is exponential regression, where the independent variable *X* functions as power or exponent. The form of this regression function is (Wahyudi, 2017):

$$Y = a\,e^{bX}$$

The current study used the following formula for demand forecasting in MS Excel:

Y= 240713*EXP(-0.175**year*).

3.2.4 Exponential Triple Smoothing. Calculates or predicts a future value based on existing (historical) values using the AAA version of the Exponential Smoothing (ETS) algorithm. The function of ETS is to estimate or calculate the future value based on the existing value. The estimated value is the continuation of the specified target date's historical value, which should be continued from the timeline.

Table 2. Forecasting The Demand of Toyota Avanza Cars in Indonesia

Year	Sales	Linear Regression	Exponential Regression	ETS	EGM (1,1,α,θ)	RGR	Mean RGR	D_t	Mean D_t
2013	213458	196235	202068	192461	213458				
2014	162070	172379	169628	170426	162070	1.76		0.13	
2015	133153	148523	142395	148392	141177	1.35		0.39	
2016	122649	124667	119535	126357	122977	1.24	1.13	0.48	0.88
2017	106064	100811	100344	104323	107123	1.17		0.54	
2018	82167	76955	84235	82288	93313	0.11		2.89	
2019	86374	53099	70711	60254	81284				
2020		29243	59359	38219	70805	1.87		0.07	
2021		5387	49829	16185	61677	1.41		0.35	
2022		-18469	41830	-5850	53726	1.25	1.32	0.47	0.43
2023		-42325	35114	-27884	46800	1.17		0.53	
2024		-66181	29477	-49919	40766	1.13		0.57	
2025		220091	240713	-71953	35511	1.1		0.6	

This ETS can be used to predict future forecasts, and the function can be used to predict future sales, inventory requirements, or consumer trends. In the current study, the ETS model was executed in MS Excel using its built-in function.

3.3 Forecast Accuracy Measurement

The performance of forecasting models is very important to be evaluated as a validation stage for models that are suitable for research data (Hakimah *et al.* 2020). The performance of the forecasting models in this study is based on the forecast errors generated by each model. The forecast error will be calculated by the Mean Absolute Percentage Error (MAPE) measurement.

$$MAPE\ (\%) = \frac{1}{n}\sum_{k=1}^{n}\left|\frac{x(k)-\hat{x}(k)}{\hat{x}(k)}\right| * 100$$

Where, $x(k)$ and $\hat{x}(k)$ are representing actual observation and the simulated (predicted) value obtained through the model, respectively. Therefore, in this study, it is often referred to as MAPE (%). The Lewis scale (Javed *et al.*, 2020a; Boamah, 2021) was used for interpreting the MAPE values:

$$MAPE(\%) = \begin{cases} < 10 & Highly\ accurate\ forecast \\ 10\sim20 & Good\ forecast \\ 20\sim50 & Reasonable\ forecast \\ > 50 & Inaccurate\ forecast \end{cases}$$

3.4 Relative Growth Rate and Doubling Time Analyses

The relative growth rate is a measure of normalized growth, which has the advantage of avoiding as much inherent scale difference between contrasting organisms as possible so that the results can be fairly compared (Pommerening & Muszta, 2015). Doubling time is one of the simplest but quite precise methods of calculating the timeframe by using numbers as growth rates in any context (Todaro & Smith, 2006). Doubling time can be calculated using the RGR approach, that is why do both of them have a close relationship, and for the application of the relative growth rate (RGR) and the doubling time (D_t) it has been calculated using the following formula Javed and Liu (2018), who proposed the concept of synthetic relative growth rate and synthetic doubling time. They used two parameters (RGR and D_t) model for growth analysis of publications. If N_2 and N_1 represent the cumulative number of car productions in the respective years t_2 and t_1 then the formulas for relative growth rate and synthetic relative growth rate are given by (Javed & Liu, 2018),

$$RGR = \ln\left(N_2/N_1\right)$$

$$RGR_{\text{synthetic}} = \theta.(RGR_{actual}) + (1-\theta).RGR_{forecast}$$

The formulas for doubling time and synthetic doubling time are given by

$$D_t = \ln(2/\text{RGR})$$

$$D_{\text{synthetic}} = \theta.(D_{actual}) + (1-\theta).D_{forecast}$$

where, θ represents the weighting coefficient, which can generally be valued at 0.5. RGR_{actual} represents relative growth rate derived through original data and $RGR_{forecast}$represents the relative growth rate derived through simulation of forecast. D_{actual} represents doubling time derived through original data, $D_{forecast}$ represents the doubling time derived through simulation of forecast. For further details about relative growth rate and doubling time analysis, Javed and Liu (2018) can be consulted.

4. Results and discussion

Ambe and Badenhorst-Weiss (2011) explain that the automotive industry has experienced strong competition on a global scale in highly competitive markets in recent years. Thus, the importance of forecasting to control the growth rate of sales growth in demand for Toyota Avanza in the next few years cannot be ruled out because historically, the industry has operated in a "push" system. In this system, Marketing and Sales uses the best forecast of market demand to communicate these forecasts to the many kinds of need as design, engineering, finance, and manufacturing teams to determine and/or model production volume (Ambe & Badenhorst-Weiss, 2011).

Data from 2013-2019 was available. Data from 2013 to 2018 was used for forecasting, and data for 2019 was used for out-of-sample testing. Using existing actual data, the simulation values were calculated using EGM (1,1, α, θ), and the results are presented in Table 2. According to MAPE, the in-sample accuracy rate of EGM 95.83% and out-of-sample accuracy was 94.11% with parameters a = 202972.723 and b = 0.1380171 and the results were revealed when following an EGM-based forecasting equation for the Toyota Avanza.

Table 2 shows that the calculation of the cumulative column used actual data from 2013-2018 and the simulation for 2019-2025 and the calculation of Mean RGR and Mean Dt is only used for comparison. RGR itself used cumulative data and Dt is obtained from RGR data that calculated using the Microsoft Excel formula = LN (2 / (RGR each year data)). Based on the data above, the result shows that MAPE% for evaluating performance produces MAPE% (In Sample) from Linear Regression, Exponential Regression, ETS, and EGM showing High Forecast which means the level of accuracy is high. Next, for MAPE% (Out Sample) from Linear Regression, ETS shows Reasonable forecast, Exponential Regression shows Good forecast, and EGM shows high forecast.

To measure the growth in sales demand for the Toyota Avanza, there are several models have been used such as in Table 2 there are Linear Regression, Exponential Regression, Exponential Triple Smoothing and Even Grey Model. Mean Absolute Percentage Error (MAPE) is used as a test tool to see each model's accuracy. After calculating using MAPE, it turns out that the MAPE% (In Sample) of the Linear Regression is 6.49%, Exponential Regression is 4.56%, ETS is 5.21%, and EGM is 4.2%. Meanwhile, the MAPE% (Out Sample) calculation results from Linear Regression is 38.52%, Exponential Regression is 18.13%, ETS is 30.24%, and EGM is (5.9%). Overall, the statistical models showed worst performance. The results compared through the MAPE test proved that EGM (1, 1, α, θ) is the best model for sales forecasting because the MAPE% values in both in sample and out of sample were <10 (high forecast accuracy) as the Lewis scale as well as literature (Quartey-Papafio *et al.*, 2020) asserts that predictions with the MAPE value of less than 10% are very accurate.

Table 3. Performance evaluation of the forecasting models

	Linear Regression	**Exponential Regression**	**ETS**	**EGM (1,1,α,θ)**
MAPE % (in sample)	6.49	4.56	5.21	4.2
MAPE % (out of sample)	38.52	18.13	30.24	5.9

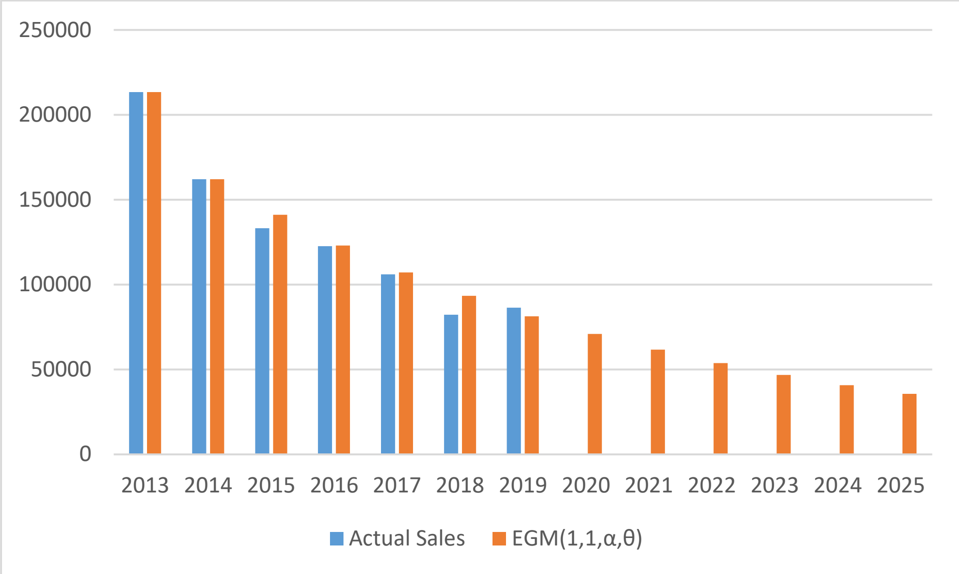

Figure 2. Grey Forecasting of Toyota Avanza Cars in Indonesia

Based on the results shown in Table 3, it can be determined that the appropriate model for the demand of the Toyota Avanza is EGM (1,1, α, θ) because it has the lowest Mean Absolute percentage (MAPE) level, there are (4.2%) for MAPE in Sample and (5.9%) for MAPE out Sample. Thus, its forecast accuracy is at least 94%. According to the Lewis's scale, the forecast is "highly accurate." Based on the forecasts carried out in this study to determine the number of the demand in 2020-2025, the most suitable model is EGM (1, 1, α, θ) with parameters a = 202972.723, b = 0.1380171, θ = 0.817147419 and α = 1.

In the chart above, the red line shows the actual data from 2013 to 2019, the blue lines show the results of linear regression, the purple line shows the result of exponential regression, the yellow line shows the result of exponential triple smoothing and the green line shows the result of the Even gray model. Even though the data in Figure 2 shows many declines, it is not an oddity data because it proves that existing data does not always increase or fluctuate, but there is also another data that is running down but does not indicate a bad decline or bankruptcy. Focusing on the EGM (1, 1, α, θ) that the demand forecast for the Toyota Avanza in Indonesia is experiencing stable and reasonable demand even though the data will gradually decline until 2025 compared to other data. That is why EGM is the best model that can be used for forecasting activities than other statistical models. Even though the result of the demand decreases until 2025, this does not necessarily indicate bankruptcy. In the present, many cars started to be marketed with a variety of models, colors, types and prices offered. Consumers are freer to choose the car they want, and they need now because of the large choices of cars being a sale. From that factor, sales of the Toyota Avanza continue to decline. However, even though it continues to decline, this car still holds the record with the highest sales in Indonesia, as evidenced by the celebration of the highest achievement of Avanza sales in 2019 as it sells 1.8 million units during 16 years of career in Indonesia and there has never been a single car that has been able to touch this achievement in Indonesia's automotive history (CNN, 2020). However, in light of the forecasts, the long-term sustainability of this success is less likely.

5. Conclusion and recommendations

The existence of a stable demand makes economic activity good and easy to control. To monitor and control the growth of demand for goods, forecasting should be used to estimate the amount that can be obtained. In this background, the current study was initiated where the Toyota Avanza cars sales in Indonesia were forecasted. When viewed from the actual data, it can be seen from the beginning of the sales that Toyota Avanza has continued to decline since 2014. Forecasting was done using one grey model and three statistical models. All models' accuracy was tested using Mean Absolute Percentage Error. It was found that the even grey forecasting model EGM (1, 1, α, θ) is very accurate when compared with the other three methods with an accuracy rate of 95.8% in-sample and 94.1% out of sample. The model predicted a decline in the sales of Toyota Avanza till 2025.

The study hopes that this research can be useful for Toyota Avanza Indonesia and allows them to make better plans to improve sales performance. The company should also expand market networks in the domestic and international area and bring new innovations into the car so the Toyota Avanza can develop better in the future and be able to achieve a good increase. Another suggestion is to introduce better alternatives, especially to tap the market of the consumers interested in electric vehicles, which has recently gained widespread attention. Also, in the future, the performance of the Toyota Avanza car's competitors can also be forecasted to get the overall picture of the industry and consumer preferences.

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Grey Forecasting of Inbound Tourism to Bali and Financial Loses from the COVID-19

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Abstract: Management and planning in the Indonesian tourism industry is an important matter. It involves responding to changes and uncertain conditions, especially in the tourism industry sector in Bali, Indonesia. Bali is a tourist spot that relies on foreign tourists. When a situation is not conducive, such as the COVID-19 outbreak that befell unexpectedly, proper management and planning are challenging without accurate forecasts. The current study used the Even Grey Forecasting model EGM (1,1,α,θ) to forecast the number of tourists to Bali, a famous tourist spot in Indonesia, and the approximate financial loss incurred from the pandemic in 2020 is quantified. These objectives are achieved through the data collected from the Bali statistical agency and analyzed through the grey model and some mathematical computations. The results indicated that the pandemic's impact on inbound tourism was severe, and the economy needs some time to recover. The study reported a loss of more than $7.3 billion to Bali due to the COVID-19 outbreak. It is possibly the first study of its kind, and its findings are important for the policy-makers, Tour & Travel service providers, and tourism-related businesses.

Keywords: Tourism; Bali Indonesia; Grey Forecasting; Financial Loss; COVID-19

1. Introduction

Indonesia is one of the tourist destinations that are in great demand by foreign and domestic tourists. The tourism industry in Indonesia has shown sustainable growth both in income and in the number of tourists. One of the tourist destinations in great demand by foreign and domestic tourists in Indonesia is the island of Bali. Bali has succeeded in becoming a leading tourist destination in Indonesia since the late 1960s (Yamashita, 2012). The international event quoted from the travel media of the United States, namely Travel + Leisure in the Best Island Category in the World 2019, consists of 15 beautiful islands. The island of Bali is in third place this year, down one place from 2018, where Bali is in second (Silvita, 2019). Bali is also known for its unique and rich culture, cultural activities, and sites.

Tourism plays a critical role in Bali's economy. In the last few decades, this sector has shown a remarkable increase. The tourism industry also has enormous and diverse economic potential that can drive economic growth (Haryanto, 2020). Although the economy in the tourism industry continues to develop, there are also significant obstacles. Such as unexpected events or natural disasters that occur. Like in 2020, when the novel coronavirus (COVID-19) devastated Bali. As a result of the COVID-19 pandemic, Bali's economic performance in 2020 has experienced a sharp decline, as shown in Table 1. From the demand side, the decrease in the output of the Balinese economy is due more to the decline in foreign exports and government consumption. And the slowdown in household consumption growth. This situation is caused by the COVID-19 pandemic, forcing several countries to enforce and

Table 1. Financial Report for the Province of Bali, 2019 to 2020 (*Source*: BI, 2021)

Indicator	2019				2020			
	I	II	III	IV	I	II	III	IV
Economic Growth (%, yoy)	5.98	5.64	5.28	5.51	-1.20	-11.06	-12.32	-12.21
Gross Regional Domestic Product (Rp. billion)	39.085	40.258	41.509	41.843	38.614	35.807	36.393	36.735

restrict travel strictly. As a result, the tourism industry, one of Bali's economic supports, was seriously affected as the number of tourists declines.

The COVID-19 outbreak was unexpected, and became one of the most significant things that ever happened to Bali's tourism industry (see Table 2). Its effect can be long-lasting. There is hardly any country or industry that is not affected by the pandemic (Irfan *et al.*, 2021; Mahmoudi *et al.*, 2020). Thus, the tourism industry of Indonesia is no exception. It can be said that the extent to which business actors can survive to keep the tourism industry going (Bhaskara & Filimonau, 2021). However, studies about disaster management in tourism still lack due to disasters that rarely recur (Seraphin, 2019). The COVID 19 pandemic can be used as a lesson to prepare preparedness for factors that can affect the tourism business, which can provide lessons for considering future business planning and can be helpful in cases of disasters or crises that can reoccur (Ghaderi *et al.* 2015). This study examines the impact of COVID-19 on the tourism business in Bali, a popular destination in Southeast Asia, one that has many foreign tourist arrivals.

The paper's structure is as follows: The first section is an introduction, which is followed by a section on literature review. This section discusses the tourism industry in Bali, the origins of COVID-19 in Bali, the Campaign for the cleanliness, health, safety, and environmental (CHSE) in Bali, and Grey forecasting theory. Later, we have a section on research methodology that describes the data collection strategy, all forecasting techniques that will be used, and the forecasting accuracy measurement method. All data obtained in the research methodology will be processed in the fourth section, producing forecasts of inbound tourism to Bali. Later, the approximate financial losses faced by Bali during the COVID-19 pandemic. From the research data, it can be concluded that the COVID-19 pandemic has

Table 2. Number of International Tourist Arrivals in Bali from 1997 to 2020 (*Source*: Putra, 2008; BPSPB, 2020)

Year	Number of tourists	Important incident
1997	1,230,316	Asian Economic Crisis
1998	1,187,153	Reform Movement
1999	1,355,799	
2000	1,376,839	
2001	1,356,774	9/11 terrorist attacks in New York
2002	1,285,844	The First Bali Bombings
2003	994,616	Spread of SARS and bird flu
2004	1,458,309	
2005	1,386,449	The Second Bali Bombings
2006	1,262,537	
2007	1,668,531	
2008	2,085,084	
2009	2,385,122	
2010	2,576,142	
2011	2,822,670	
2012	2,949,332	
2013	3,278,598	
2014	3,766,638	
2015	4,001,835	
2016	4,297,937	
2017	5,697,739	Agung Mountain Eruption
2018	6,070,473	
2019	6,275,210	
2020	1,069,473	The COVID-19 pandemic

a significant impact on the number of tourists who come back. These things are explained in sections 5 and 6, which contain conclusions and solve the problems that are currently happening.

2. Literature Review

2.1 Tourism industry of Bali

Bali is a popular tourist destination that can provide significant foreign exchange to Indonesia. The fast-growing tourism industry also influences Bali's contribution to economic growth. However, the tourism industry also has other factors that may disrupt the economy, such as natural disasters and other accidents. In the past, Bali has suffered several consecutive tragedies such as terrorist actions (Hitchcock & Putra, 2005) and various natural disasters such as earthquakes and volcanic eruptions (Beirman, 2017). The results of this investigation can help the idea through) explaining how tourism businesses can quickly adapt to and recover from natural disasters and crises. This will add tourism management theory to be studied (Blackman *et al.*, 2011). This study will examine how business players in the tourism industry in Bali must adapt to the current situation with proper management and planning to recover after being affected by the COVID-19 pandemic.

The literature emphasizes the need to know the types of hazards and crises that can trigger successive disasters when they impact business and develop preparedness and rapid response in disaster preparedness (Hall & Prayag, 2020). The theory aims to learn about events and apply proper management and planning to prepare and restore business effectively and gradually. However, another idea shows that learning is not always proven and occurs (Filimonau & De Coteau, 2020) because follow-up disasters or crises arise suddenly and are difficult to predict (Hall *et al.*, 2016).

The COVID-19 epidemic in Bali, Indonesia, produced a lot of detrimental impacts on global tourism. Many people say that altering the present international tourism scenario needs all tourist companies to review their business models and then change operational behavior to reflect new government mandates and customer expectations (Hall *et al.*, 2020). Being hit by natural disasters or incidents and crises is an interesting object of research. Experiences that occur several times in tourism destinations can provide learning and provide the skills needed to deal with disasters in the future (Jiang & Ritchie, 2017), one of which is related to the impact of the COVID-19 pandemic. Past experiences, as mediated by learning, could inspire tourist firms to develop market strategies for planning events and dealing with future disasters and crises (Cioccio & Michael, 2007). The 'correct' mix of talents and resources boosts industrial resilience (Faulkner, 2001). Every event that influences or is connected to the tourist sector can teach natural and human resources, allowing for learning in the tourism industry (Filimonau & De Coteau, 2020).

2.2 Bali during the COVID-19 pandemic

The pandemic also hit the tourism sector hard. Until the end of 2020, a total of 743,198 patients had confirmed positive for COVID-19. The decline in local and foreign tourists also significantly impacted the economic road, especially in Bali, where the area relies heavily on local and foreign tourists. The data at the Indonesian statistics agency suggests that the decline during the pandemic year (2020) is significant. It can be seen from Table 3 that a very significant decline occurred at the beginning of the COVID-19 pandemic that hit Indonesian tourist hot spots like Bali. In this case, the government has taken several steps to fight the COVID-19 pandemic. The government provided facilities and provisions that must be carried out in running a business in the tourism sector. Therefore, the tourism industry needs new management and planning in dealing with the economy in an arguably uncertain situation. There is also a need to learn from international best practices in this regard.

Table 3. The number of international tourist arrivals in Bali in 2020 (*Source*: BPSPB, 2020)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of Tourists	536,611	364,639	167,461	379	36	45	16	12	8	63	53	150

2.3 Campaign for the Cleanliness, Health, Safety, and Environment (CHSE) in every tourist spot

The Indonesian government has enforced a strict health protocol known as the "CHSE" (Cleanliness, Health, Safety, and Environment) in the tourism sector and creative economy in the country since September 2020 (Kemenparekraf, 2020). Under the Ministry of Tourism and Creative Economy, the CHSE provides opportunities for the tourism industry in Indonesia. Thus, a tourism industry such as Bali can conduct business and tourism by first obtaining a CHSE certification. Another goal of establishing the CHSE is to increase efforts to prevent and control COVID-19 in public places and facilities to avoid new epicenters or clusters during the pandemic.

CHSE has criteria that must be applied and implemented by every business entity in the tourism and creative economy sector. The essential thing in this regulation is Social Distance, which provides approximately 1 meter for each visitor when traveling in Bali. There are also masks that every tourist should wear. It is mandatory to wash your hands and use a hand sanitizer every time you enter or leave tourist attractions and every time you make a transaction. With the stipulated regulations, it is hoped that it can run and bring in visitors. Entrepreneurs in Bali must have excellent and proper management. First, they must provide the equipment and infrastructure to support CHSE regulation.

Dealing with virus spreaders and pandemics that occur suddenly is not an easy thing. It requires mature methods and strategies as well as the right skills in dealing with them. By maintaining and using the correct planning, the economy in the tourism industry, especially in Bali, can recover or even develop. In this case, several things must be applied.

2.4 Grey Forecasting

Forecasting future developments has always been important in various fields, one of which is the tourism industry. To get a reliable forecast, it must be based on the principle of nature or the actual situation (Cui *et al.*, 2013). However, finding the available natural principles is very difficult in physical and general systems (Lin *et al.*, 2009). Therefore, taking forecasting from previous data observations is a practical alternative. To solve this problem, Deng proposed the grey system theory and captured the trend of systems development while focusing on insufficient knowledge and uncertainty (Deng, 1982). Grey system theory enables modeling with limited data and uncertainty (Liu & Lin, 2006). Grey forecasting models are an important part of the grey system theory and have seen applications. All natural systems can be classified as grey systems as information in such systems is always insufficient (Esangbedo *et al.*, 2021), including the tourism sector (Javed *et al.*, 2020b). Therefore, the application of the grey forecasting model to forecast inbound tourism to Bali is a feasible step.

EGM (1,1,α,θ) is a generalized form of the classical EGM (1,1), and was proposed by Javed *et al.* (2020a). Its computational steps are as follows.

Let the actual data sequence be $x^{(0)} = \left(x^{(0)}(1), x^{(0)}(2), \ldots x^{(0)}(n)\right), x^{(0)}(k) \geq 0,$ and the compatibility series of $x^{(0)}$ accumulated fractional data is $x^{(a)} = \left(x^{(a)}(1), x^{(a)}(2), \ldots x^{(a)}(n)\right)$ where, $x^{(a)}(k) = \sum_{i=1}^{k} \left(\frac{x^{(0)}(i)}{i^{1-a}}\right), k = 1,2,\ldots,n.$ The average sequence of neighbouring $x^{(1)}$ will be $z^{(1)} = \left(z^{(1)}(1), z^{(1)}(2), \ldots z^{(1)}(n)\right)$. The Ordinary Least Square approach can be used to estimate parameters *a* and *b* and the time response function of the model is stated as

$$\hat{x}^{(a)}(k) = \left(x^{(0)}(1) - \frac{b}{a}\right) e^{-a(k-1)} + \frac{b}{a} k = 1,2,\ldots,n$$

Inverted conformable fractional accumulation is required to extract the real $\hat{x}^{(0)}(k)$ data sequence simulation from the $\hat{x}^{(a)}(k)$ accumulated data sequence simulation is performed through the following regressive formulation

$$\hat{x}^{(0)}(k) = k^{1-a}\left(\hat{x}^{(a)}(k) - \hat{x}^{(a)}(k-1)\right), k = 1, 2, \ldots, n;\ \hat{x}^{(0)}(0) = 0$$

And the time-response function of $x^{(0)}$, which is an exponential function of time, is performed by

$$\hat{x}^{(0)}(k) = k^{1-a}(1-e^{a})\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-a(k-1)}, k = 1,2,\dots,n$$

EGM (1,1,α,θ) has the advantage of being able to change parameters of α and θ with data variance as data noise can have various shapes. Contrary to the conventional model EGM (1,1), the two parameters of the EGM model (1,1,α,θ) are not static but dynamic and change their values as data noise varies, so that we generate relatively more precise forecasts. The complete detail on the model is available in Javed *et al.* (2020a).

3. Research Methodology

3.1 Data Collection

Data collection was conducted in Indonesia, and research was conducted entirely online. By examining various sources found and understanding the conditions and situation in Bali for visiting tourists. After collecting all the data, strategies and plans can provide predictions to develop Bali's tourism industry correctly. Data on "The Number of International Tourist Arrivals in Bali from 1997 to 2020" was obtained from Bali in Political Power and the Bali Provincial Statistics Agency, i.e., BPSPB (2020). Data for "The Financial Report for the Province of Bali 2019 Q1 to 2020 Q4" were obtained from Bank Indonesia on the website BI (2021). Data for "International Tourist Arrivals" in Bali in 2020 were obtained from BPSPB (2020). The "Actual Data" contained in the "Forecast Results of Tourist Visitors" was obtained from BPSPB (2020). "Revenue Data" on "Bali Tourism Revenue" was obtained from the World Tourism Organization, i.e., UNWTO (2021).

3.2 Forecasting techniques

In the current study, the Even Grey Model EGM (1,1, α, θ) was used to predict inbound tourists to Bali. For comparative analysis, Linear Regression (LR), Exponential Regression (ER), and Exponential Triple Smoothing (ETS) were run on Microsoft Excel. EGM (1,1,α,θ) was built on the excel using the steps mentioned by Javed *et al.* (2020a).

3.3 Measurement of Forecast Accuracy

The most common summary indicator for assessing the accuracy of population forecasts is the mean absolute percent error (MAPE). Although MAPE has many desirable parameters, we argue that the widespread practice of exclusively using it to evaluate population forecasts should be modified, both normatively and relatively. MAPE is reported as a percentage and with the following formula.

$$MAPE\ (\%) = \frac{1}{n}\sum_{k=1}^{n}\left|\frac{x(k)-\hat{x}(k)}{\hat{x}(k)}\right| \times 100$$

Here, $x(k)$ and $\hat{x}(k)$ are representing actual and the model-based data, respectively. The effectiveness of MAPE has been used in several studies, where prediction making using a grey model is involved. The use of the Lewis MAPE value scale is used to measure the accuracy of forecasts. This scale is given below (Javed *et al.*, 2020b):

$$MAPE(\%) = \begin{cases} < 10 & Highly\ accurate\ forecast \\ 10-20 & Good\ forecast \\ 20-50 & Reasonable\ forecast \\ > 50 & Inaccurate\ forecast \end{cases}$$

4. Results and discussion

4.1 Forecasting inbound tourists to Bali

In the current study, a forecasting method is used to determine the number of tourist visitors who come to Bali to plan an increase in visits to increase the effectiveness and efficiency of implementing this strategy. For the forecasting, we used data from tourists visiting from 2009 to 2017. Data from

Table 4. Forecasting of inbound tourists to Bali

Year	Actual Data	EGM (1,1,α,θ)	Linear Regression	Exponential Regression	ETS
2009	2,385,122	2,385,122	2,091,236	2,662,152	2,562,216
2010	2,576,142	2,363,454	2,451,094	2,940,368	2,922,318
2011	2,822,670	2,640,191	2,810,952	3,247,660	3,282,420
2012	2,949,332	2,949,332	3,170,810	3,587,067	3,642,522
2013	3,278,598	3,294,670	3,530,668	3,961,944	4,002,624
2014	3,766,638	3,680,444	3,890,526	4,375,999	4,362,726
2015	4,001,835	4,111,388	4,250,384	4,833,326	4,722,828
2016	4,297,937	4,592,791	4,610,243	5,338,447	5,082,930
2017	5,697,739	5,130,562	4,970,101	5,896,358	5,443,032
2018	6,070,473	5,731,301	5,329,959	6,512,574	5,803,134
2019	6,275,210	6,402,380	5,689,817	7,193,191	6,163,236
2020		7,152,037	6,049,675	7,944,937	6,523,338
2021		7,989,470	6,409,533	8,775,246	6,883,440
2022		8,924,959	6,769,391	9,692,330	7,243,542
2023		9,969,985	7,129,250	10,705,256	7,603,644
2024		11,137,373	7,489,108	11,824,041	7,963,746
2025		12,441,451	7,848,966	13,059,748	8,323,848
MAPE% (in-sample) (2009 – 2017)		4.63%	6.93%	16.44%	15.48%
MAPE% (out-of-sample) (2018 – 2019)		3.81%	10.76%	10.96%	3.09%

2018 to 2019 was used for out-of-sample testing. To ensure accuracy, we use mean absolute percentage error (MAPE).

Based on data analysis from four forecasting methods, the EGM (1,1,α,θ) showed the highest accuracy in both in-sample and out-sample testing in determining the income and losses of the tourism industry in Bali. In-sample is the data we use for forecasting, and out-of-sample is the data we don't use for forecasting but use to see whether our forecast is matching with it (reality) or not. According to the Lewis scale, a forecast error of less than 10% shows a highly accurate forecast. Hence, EGM (1,1,α,θ) is comparatively most accurate. The results are shown in Table 4 and Figure 1. With more than 95% accuracy, the grey forecasting revealed that 7,152,037 (7.2 million) tourists were expected in 2020 but due to the pandemic only 1,069,473 (1.07 million) visited. Thus, this gap can be used to quantify the financial losses that Bali incurred as a result of fall in revenue per tourist. In the succeeding section the financial losses will be estimated.

4.2 Bali's financial loss due to the COVID-19 outbreak

The COVID-19 pandemic that occurred in Bali greatly impacted the economy in the tourism industry. Many tourist attractions cannot operate due to the absence of tourists who wish to visit, especially foreign tourists who have not entered the Bali area. This is a loss to the income of the tourism industry in Bali.

The data presented in Table 5 shows that revenue per tourist to Indonesia increased from $1090 in 2016 to $1142 in 2019. Hence, in 2020 it was likely to be more than $1142. Let's assume it to be $1142 in 2020 (though the real value is expected to be greater than it). We presume this increasing trend holds for Bali as well. Meanwhile, because of the COVID-19 outbreak in Bali, the actual revenue was $807. The forecasting model revealed to us that 7,152,037 tourists were expected to visit Bali in 2020. Let's assume the revenue per tourist to Bali in 2020 is equal to the average revenue per tourist to Indonesia in 2020. Therefore, the estimated expected revenue in 2020 from inbound tourism, denoted by R (2020), is calculated as

$$R\ (2020): \quad 7{,}152{,}037 \times \$\ 1142 = \$\ 8{,}167{,}626{,}254$$

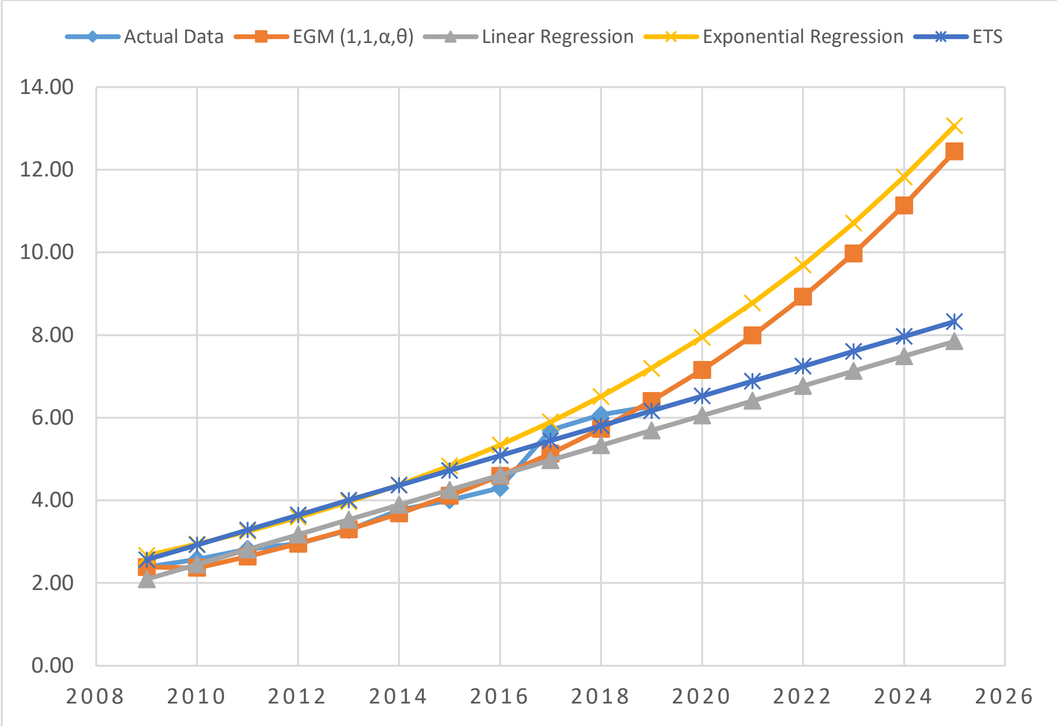

Figure 1. Forecast of inbound tourists (in millions) to Bali till 2025

The tourism sector plays a vital role in the economy of Bali. Bali should have an income of around \$8,167,626,254 in 2020, but due to the COVID-19 pandemic in 2020, Bali's income is just \$863,027,466. Bali's estimated financial loss due to COVID-19 in 2020, denoted as B (2020), can be,

B (2020): \$ 863,027,466 - \$ 8,167,626,254 = -\$ 7,304,598,788

Thus, Bali incurred an estimated loss of over \$7.3 billion. Considering the increase in revenue per tourist, a trend that was reversed by the pandemic, one can argue that this value is an optimistic estimate as the real loss is likely to be higher. The prolonging of the fight against the pandemic will only increase losses as using a similar methodology, losses can be estimated for the year 2021 as well if the world failed to contain the virus by the end of the year.

4.3 Discussion

Based on the data that has been discussed in the previous chapter, the ability to adapt to the current situation is very influential on the tourism industry. This is because the current situation influences the tourism industry. That way, entrepreneurs involved in and participate in the tourism industry can survive in any condition. It can be seen from the data of tourists who visited Bali when the COVID-19 pandemic hit them. There are step-by-step increases that have occurred. There was an increase after business actors participated in government regulations. It can be seen that after the government sets rules for the tourism industry, namely the CHSE, business actors who are ready for these provisions will have a positive impact on their business. Business actors who continue to invest in advertising in the tourism industry will have a good effect, especially after the pandemic ends and holidays arrive.

Table 5. Inbound Tourism in Indonesia

Year	Number of Tourists in Indonesia[1]	Indonesia's Revenue (\$)[1]	Revenue per tourist (\$)[2]
2016	11,520,000	12,566,000,000	1091
2017	14,040,000	14,692,000,000	1046
2018	15,810,000	17,915,000,000	1133
2019	16,110,000	18,404,000,000	1142
2020	4,020,000	3,244,000,000	807

[1]UNWTO (2020)
[2]Self-Calculated by dividing revenue with tourists

Many things must be done to keep fighting and survive the demanding conditions that affect income and the economy. Continue to constantly develop in management and planning and strategies that will help revenue and visiting tourists. Managing a business also requires a lot of experience and knowledge. A lot of experience, expertise, and accuracy can help decide strategy and plan for the future (Linnenluecke *et al.*, 2012). By following some suggestions in managing the tourism business and implementing it, it is hoped that it can help the economy in the tourism industry, which looks like the COVID-19 pandemic. The increase in the tourism industry in Bali must be driven by investment in management so that planning and management can develop properly. A competent workforce shows an industry's competitiveness in dealing with disasters and crises that can immediately help recovery from ongoing changes (Wang *et al.*, 2020).

5. Conclusion and recommendations

The findings of this study provide insight into information that can help small and medium enterprises and Tour & Travel service providers affected by the COVID-19 pandemic. Small and medium entrepreneurs and Tour & Travels service providers can appropriately adapt to the current situation and plan and improve it. Furthermore can affect the increase in tourists visiting Bali. Improving infrastructure, hospitality, and security can potentially impact increasing tourists and lead to better income. It is hoped that the COVID-19 pandemic will end soon, and the spread of the virus will not happen again, and the economy in the tourism industry sector will run normally. Also, some recommendations can be made at this stage, which are listed below.

5.1 Change the paradigm of advertisement

Advertising tourism with the concept of "hard selling" is no longer an option in this unfavorable situation. The number of people who want to travel and take vacations has decreased. Therefore, the concept of advertising with "soft selling" can be an option. Soft selling is advertising in displaying brands and brands in a subtle and non-aggressive manner. Soft selling is designed to avoid customers feeling pressured by heavy advertising. Soft selling is also a technique in persuasive and subtle selling. Techniques such as soft selling may not significantly impact the beginning of advertising but will eventually help drive continuous sales in the next period (Kenton, 2019). The use of soft selling in the tourism industry can influence the introduction of tourism itself. This can introduce the tourism industry and the tourist attractions themselves to various circles. With soft selling, people will be able to recognize and make a holiday wishlist for the future when the situation has started to improve from the conditions of the COVID-19 pandemic. This could have a significant impact in the future.

5.2 Develop new business models

Tourism entrepreneurs must also adjust to the current situation, seeing the changing habits of tourists. Activities in the tourism industry must also be able to follow market needs. In this case, it can be in the form of tours and trips. Changing travel schedules more flexibly and visiting more beautiful tourist attractions can be an option. Supported by Bali's friendly and relaxed nature, travel in Bali can focus more on outdoor tourism. One of the visits that can be an option for tour & travel entrepreneurs is to visit to enjoy views of rice fields and mountains. The tourism industry in Bali can also change the concept from indoor to outdoor. Where the air circulation is smoother, and visitors feel the cool breeze. This is to avoid spreading the virus because, in a closed room, the virus will spread more easily. Restaurants or cafes can adapt this concept. Business actors can give tourists a discount for each vacation visit and a gift from each completed tour in financial management. This will provide them with a good image in traveling.

5.3 Improving quality control

Quality control on visitors must also be closely monitored, starting from tourist trips using public transportation or private transportation. Before traveling, it is mandatory always to check health and test PCR for COVID-19. Supervision of visitors can also be captured and spread in the media. This can provide a good perspective in the community where people will feel more secure and visit. Advertising reasonable and correct quality control can also be an example for other industries related to the tourism industry. With this, it will improve the economy after the impact of the COVID-19 pandemic. Also, the vaccination rate should be improved to ensure the long-lasting success of other initiatives.

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