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Research Article

Mangrove Afforestation and Reforestation in Coastal Areas of the Bushehr Province

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Abstract

Given the pressure of population growth, economic difficulties, and climate change, the mangrove forests of Iran need a management plan based on forest protection, reforestation, and afforestation. In this study, the sustainability of mangrove forests in coastal areas of the Bushehr Province in the north of the Persian Gulf was evaluated using two criteria including "extent of forest resources" and "forest health and vitality" from 1993 to 2009. Indicators of area changes, density changes or survival rate, natural regeneration establishment, and height growth were measured as part of the assessment method. Google Earth images were visually interpreted, and a random sample technique was used. A total of 70 circular samples of 100 m^2 were chosen. The results showed that *Avicennia marina* was planted in 7 sites in Kangan and Dayyer townships on the coasts of the Bushehr Province. Out of 370 ha of the plantation, only 42.4 ha remained, showing an area reduction of 88.5% and an average survival rate of 48.5%. Forest planted density averaged 6635 seedlings per hectare which has decreased by 69.5% (i.e. 4611 seedlings/ha). The decreased area in the Khan site was 91% and in the Basatin site was 52.5%. It is necessary to take into account management measures to improve the status of forest sustainability indicators on the coasts of the Bushehr Province, especially in the process of site selection, to improve the success rate of reforestation and afforestation plans.

Key words: Afforestation, *Avicennia marina*, Natural regeneration, Reforestation, Seedling survival rate.

1. Introduction

The importance of mangrove forests to preserve fishery species, timber production, medicinal use, livestock grazing, and its value in ecotourism and education has made their conservation and development more important than ever. Today, in addition to conservation, mangrove forests management pays great attention to developing these forests to benefit from their ecological services. (Worthington et al., 2020; Hoberg, 2011). These forests are essential ecosystems for coastal communities due to their vast variety of ecosystem services, such as wave protection, erosion control, animal grazing, commercial fish breeding and fuel provision (Gandhi & Jones, 2019). However, the destruction and extinction of these sites have been intensified worldwide (Ellison, 2015) and their global distribution and expansion are declining due to human activities (Friess et al., 2019; Queiroz et al., 2020). Mangroves are exposed to a wide range of natural and human threats throughout Iran and in the world. The main threats to mangrove forests are land-use change, urban development, infrastructure and tourism, aquaculture, grazing, pollution, illegal logging, sedimentation, water flow change and drought. (Polidoro et al., 2010; Gabler et al., 2017; Mafi-Gholami, et al., 2017;

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Zamani Afshar et al., 2022; Behrouzi Khorgou et al., 2022). The direct result of these disturbances is the reduction of growth and health of mangroves, global warming and other climate changes, declining coastal water quality, biodiversity loss, degradation of coastal sites and the destruction of the resources needed by human communities in recent decades (Mumby et al., 2004; Nagelkerken et al., 2008; Walters et al., 2008).

In Iran, mangrove forests are located along coastal areas of the Persian Gulf and the Gulf of Oman in the three provinces of Bushehr, Hormozgan, and Sistan and Baluchestan (Zahed et al., 2010). Because of their sensitive biophysical resources, site importance, breeding, biodiversity, richness of species, existence of endangered and rare species, and pollutants sensitivity, all of Iran's mangrove forests are among the most sensitive marine areas of the country (Danehkar, 2006; Taghizade et al., 2009). Therefore, high sensitivity of these sites, their very valuable and useful services and their threat from both human and natural aspects, causes their rehabilitation and development to benefit from its services, in the focus of land planners and conservation authorities. In this regard, Lewis et al. (2019) stated that understanding the ecology of different mangrove species, hydrological patterns of species location and recognizing changes already occurred in the selected environment, are important factors in the success of mangrove sites. Marchand (2008), working on a mangrove plantation in Vietnam estimated that survival in a 580ha area in a period of four years (1989-1993) was only 40 percent. Kodikara et al. (2017) evaluated the effectiveness of mangrove planting schemes in Sri Lanka. The results showed that from about 1000 to 1200 hectares of planting mangroves, only about 200 to 220 hectares were successful. Survival rate was estimated from 0 to 78%, and 67.36% of the afforested sites could not be established.

Monitoring hand-planted areas after finding a good location for mangrove planting is one of the most important pillars of success in mangrove forest rehabilitation and development programs, thus the research and assessment of sustainability indicators in these areas is critical (Lewis, 2005). Indicators such as changes in the area, plant density or survival rate, forest vigor, natural generation establishment, and height growth rate to assess the sustainability of planted sites can be seen in various studies (O'Connell, 2022; Lewis, 2019; Balk & Friess, 2016; Bosire et al., 2008). In fact, based on the evaluation of sustainability indicators results, the performance of afforestation projects can be judged and steps can be taken to achieve sustainable forestry.

Mangrove forests of Iran have a small area that grow naturally and their entire surface is considered a protected area or international wetland. The development of these forests is very necessary to benefit from their services. So far, no study was conducted to measure the success rate and to assess the sustainability of mangrove forests in the Bushehr Province. The results of this study will help national and provincial managers and decision makers to consider the support measures needed for afforestation sites and can be a guide to select new afforestation sites.

2. Materials and methods

2.1. Study area

The coasts of the Bushehr Province are located in the western part of the northern coasts of the Persian Gulf. The mangroves of the Bushehr Province are among the plant communities of Khalij-Omani ecoregion of Iran. The mangrove sites of this province are dominated by *Avicennia marina* (Forssk.) Vierh. (Fig. 1). Bushehr mangroves include Nayband Bay, Meleh-Gonzeh site and Dayyer port. Nayband Bay site includes the Bidkhoon and Basatin estuaries, with about 80 ha and at an elevation of 3.5 m above sea level (a.s.l.). Mangrove communities at the Mole-Gonze site are about 25 ha with about 4.5 m a.s.l. This site is part of the Monde Protected Area. The site of Dayyer port is located in the Bardestan estuary with an area of 1 ha with 4 m a.s.l. (Danehkar et al., 2012).

2.2. Research method

To evaluate and monitor mangrove forestation on the coasts of Bushehr province, the following steps were done:

2.2.1. Recognizing the environmental characteristics of hand-planted sites

At this stage, by reviewing the documents and reports available in the Department of Natural Resources and Watershed Management of the Boushehr Province and township offices, the environmental characteristics of mangrove forest

areas were determined. These characteristics included geographical location, cultivated areas, year of cultivation, and the number of seedlings planted.

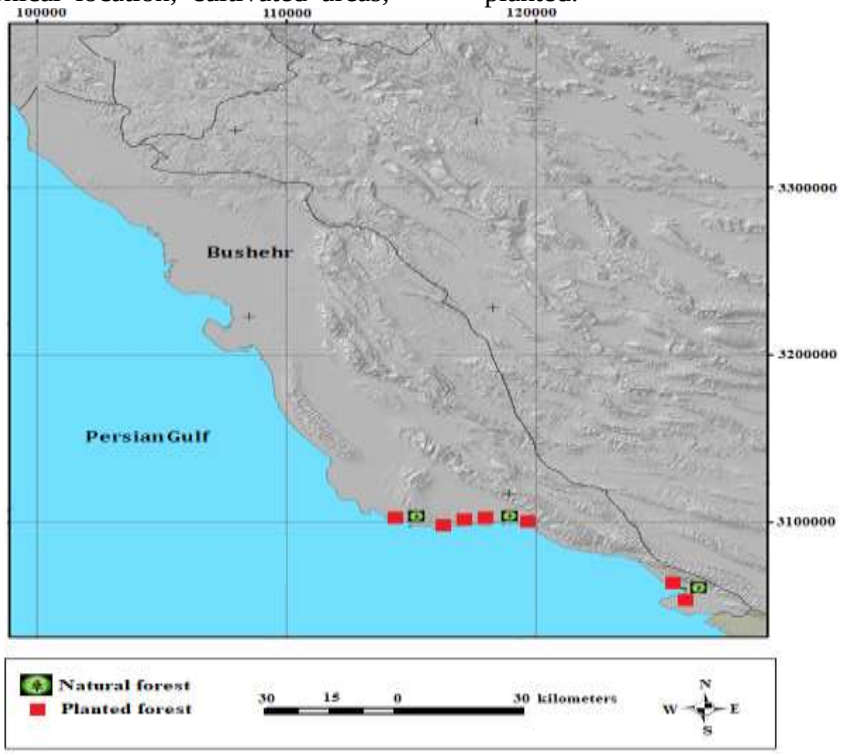

Figure 1: Location of natural mangrove forests sites in the Bushehr Province

2.2.2. Selection of criteria and indicators for evaluating forestation stands

Among seven main criteria to assess forest sustainability in national and international comparisons including 1) Extent of forest resources, 2) Biological diversity, 3- Forest health and vitality, 4- Productive functions of forest resources, 5- Protective functions of forest resources, 6- Socio-Economic-functions, 7- Legal, policy and institutional framework word (Raison et al., 2001), two criteria, i.e. "Extent of forest resources" and "Forest health and vitality" were selected for this evaluation. These two criteria were selected based on the thematic relationship which was the purpose of the study, i.e. the study of the stability of afforestation stands (O'Connell, 2022; Lewis, 2019; Boukherroub et al., 2017; Trumbore et al., 2015; Luo et al., 2010). Table 1 shows the criteria and indicators used.

Table 1. Criteria and indicators for the evaluation of the sustainability of mangrove forests stands

Criteria	Indicators
Extent of forest resources	Forest area changes (area reduction)
Forest health and vitality	Forest density changes (density reduction)
	Average height growth
	Average forest regeneration

2.2.3. Measuring of forest sustainability indicators

Google Earth images of 2021 were visually interpreted to determine the status of the indicator of changes in the forest areas. Site zones were classified into two categories: low density and high density. The planted stands were studied between 1993 and 2009 given the sufficient time for the establishment and stabilization of seedlings, it was possible to measure sustainability indicators in

them. Forest stands were separated into two density zones: low density and high density. A random sample approach using circular plots of 100 m^2 was employed to assess changes in density or survival, height growth, and regeneration rate (Nameer et al., 1992; Ukpong, 1992). Ten plots and a total of 70 samples were gathered over 7 locations. The number of trees, the number of regrowth (natural regeneration), and the height of the trees were counted in each plot. "Natural regeneration establishment" refers to trees that are now developing as seedlings producing seeds. The height of the 912 trees was measured by an altimeter. The percentage change in the area of planted sites was calculated by comparing the area under cultivation and the area measured using Google Earth. The amount and percentage of density reduction or survival rate were calculated based on the existing density estimated through sampling and the expected density (number of seedlings planted).

3. Results

3.1. Environmental characteristics of forested sites

On the coasts of Bushehr province number of 7 sites were planted in Kangan and Dayyer Townships. Out of the total of 370 ha of plantation on the coasts of the Bushehr Province, 19 hectares were done in the form of afforestation and reforestation and the rest in the form of afforestation for the development of mangrove forests (Table 2). In Basatin, Gazang, Joubrani and Khan Sites, afforestation was performed, but in Bidekhon and Bardestan sites, the operations were as afforestation and reforestation. Plantations first began in 1993 at the Moleh-Gonzeh and Joubrani sites. Number of 2455260 *Avicennia marina* seedlings were planted on the coastal line of Bushehr province by the Department of Natural Resources and Watershed Management of Boushehr Province.

In Dayyer township 2335660 seedlings and in Kangan township 119600 seedlings were planted. According to Table 2, the largest area of afforestation with 300 ha in Khan's site was done between 2007-2009. Planting distance was selected as 1.5 × 1 m at all sites. On average, the number of seedlings cultivated per hectare was 6635 individuals.

Table 2. Characteristics of mangrove forested

Township	Site	Plantation action	Year	Cultivated area (ha)	Number of seedlings planted	Planting distance (m)	Number of seedlings (per ha)
Kangan	Basatin	Afforestation	2006	8	53000	1.5 × 1	6625
	Bidekhon	Afforestation & Reforestation	2006	10	66600	1.5 × 1	6660
Dayyer	Moleh-Gonzeh	Afforestation & Reforestation	1993-2007	8	53000	1.5 × 1	6625
	Gazang	Afforestation	2009	40	266000	1.5 × 1	6650
	Joubrani	Afforestation	1993	3	20000	1.5 × 1	6666
	Khan	Afforestation	2007 - 2009	300	1990000	1.5 × 1	6633
	Bardestan	Afforestation & Reforestation	2008	1	6660	1.5 × 1	6660
		Total		370	2455260		6635

3.2. Estimation of sustainability indicators

Figures 2-4 show the density of forests in the Basatin, Bardestan and Moleh-Gonzeh sites. Site zones are divided into two classes of low and high density. Figures 5 and 6 show an overview of the current situation of low density, high density, and natural forest in the Basatin and Moleh-Gonzeh sites. The results of the visual interpretation of satellite images to estimate the remaining area of forested are shown in Table 3. According to this Table (3), the remaining forested area on the coast of the province is 42.4 ha. The percentage of area reduction was 61.6 in Kangan and 89.9 in Dayyer.

The percentage of area reduction in the Khan Site was 91%, and in the Basatin site was 52.5% (Table 3). Khan site with 5300 trees per ha and Joubrani site with only 6 trees per ha are the best and the worst sites, respectively. Joubrani and

Bardestan sites had the highest density reduction with 6660 and 5860 seedlings per ha, and generally with 0.09% and 12% survival rates, respectively (Table 3). The highest survival rate of 79.9% and the lowest one with 0.09% belonged to Khan and Joubrani sites, respectively (Table 3). The average percentage loss of forest density based on the number of lost seedlings in each township, in the Dayyer and Kangan townships obtained 28% and 42.3%, respectively (Table 3). In total, the average remaining forested density is 2024 individuals per hectare and the percentage of seedling reduction is 69.5%. Joubrani site trees with 200 cm have the highest height and Gazang trees with 50 cm has the lowest height (Table 3). In Joubrani estuary, in terms of the age of Basatin and Meleh Gonzeh cultivations, the average height of the mass is more than other areas. Maximum regeneration was in the Bidekhom site with an average of 540 seedlings per ha, and the minimum regeneration was in the Joubrani site with an average of 25 seedlings per ha (Table 3).

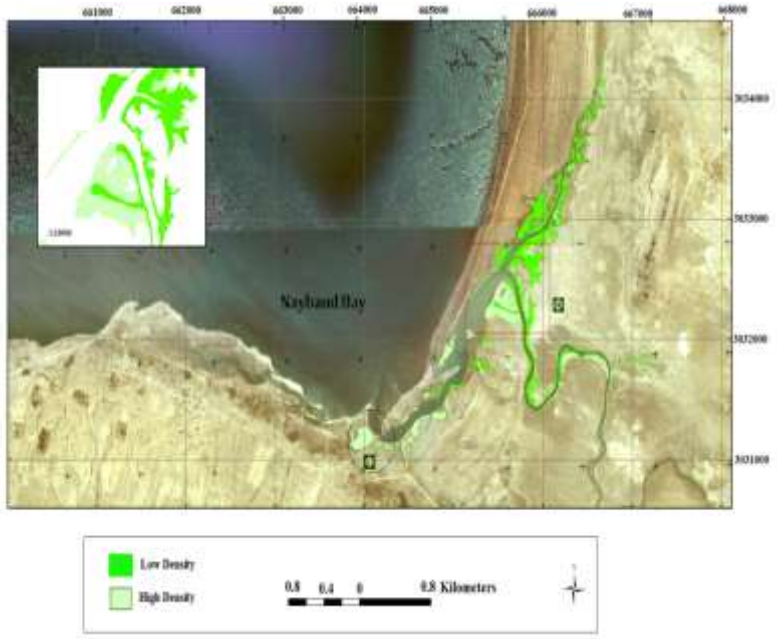

Figure 2. Mangrove zone in the Basatin Site

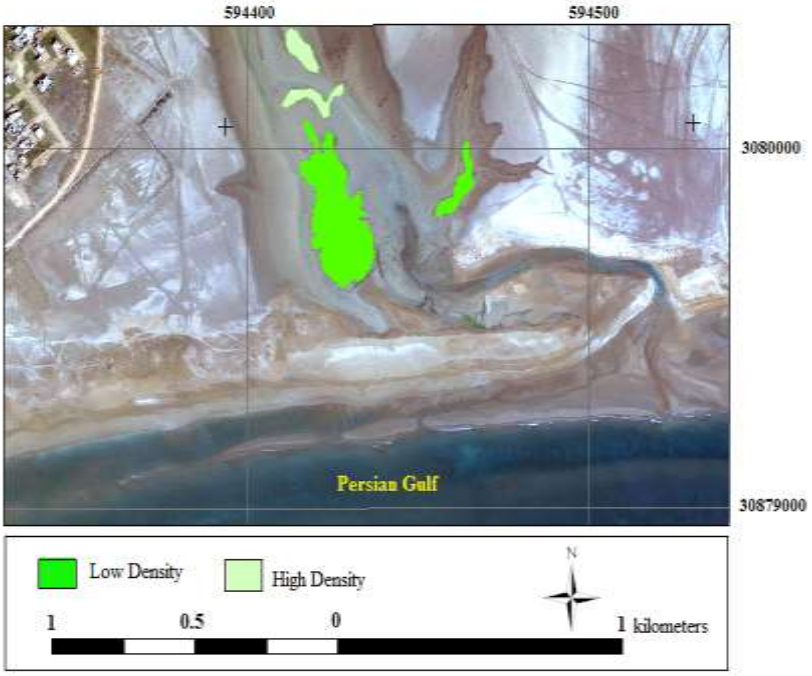

Figure 3. Mangrove zone in the Bardestan Site

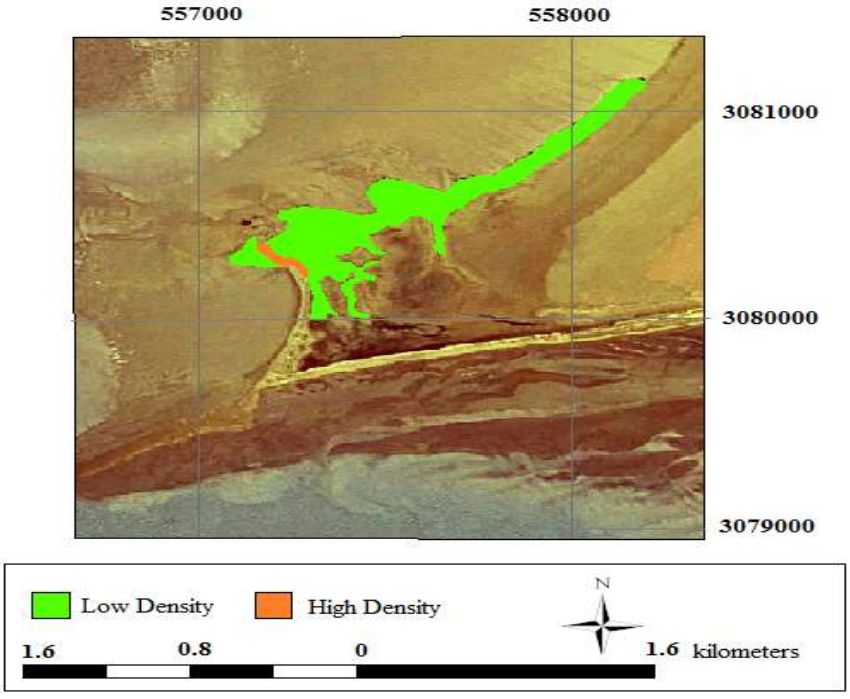

Figure 4. Mangrove zone in the Moleh-Gonzeh Site

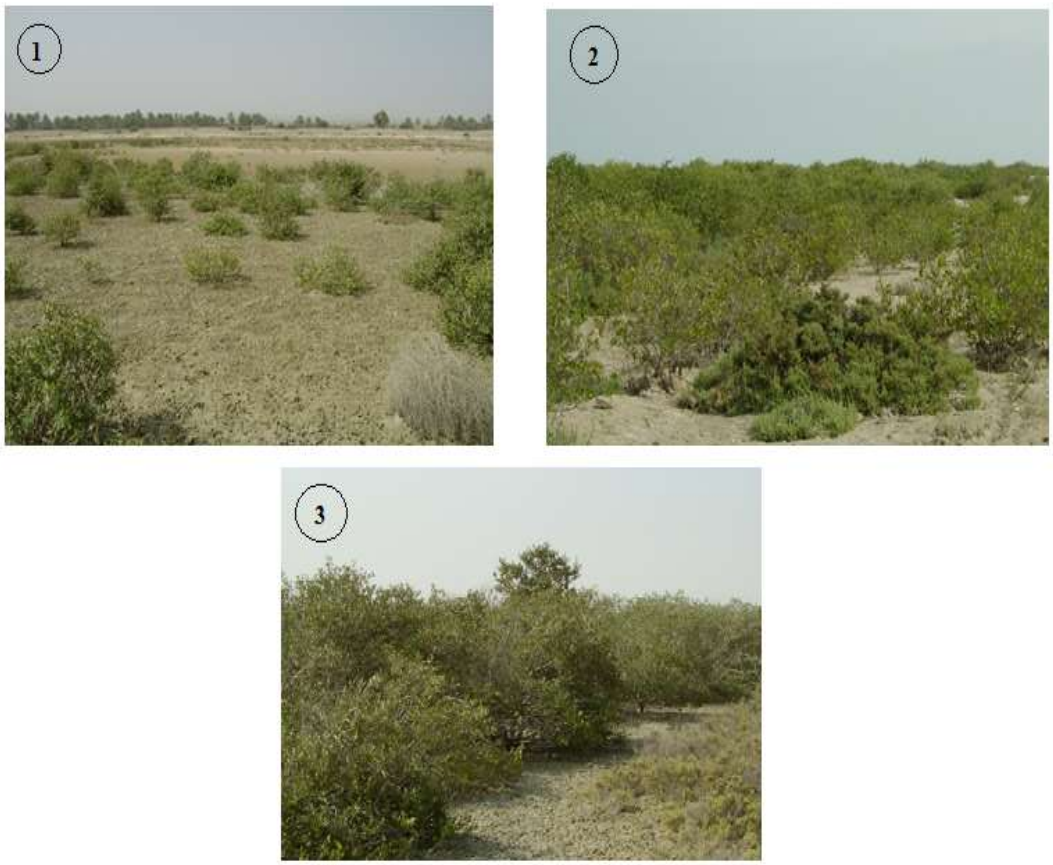

Figure 5. Mangrove overview in the Basatin site
1: Low density area, 2: High density area, 3: Natural forest

Figure 6. Mangrove overview in the Moleh-Gonzeh site
1: Low density area, 2: High density area, 3: Natural forest

Table 3. Status of sustainability indicators in planted sites

Township	Site	Plantation action	Remaining forested area (ha)	Percentage of area Reduction	Average density (per ha)	Density seedlings reduction (per ha)	Average survival (%)	Average tree height (cm)	Average natural regeneration (per ha)
Kangan	Basatin	Afforestation	3.8	52.5	4300	2360	64.9	170	350
	Bidekhon	Afforestation & Reforestation	3.1	69	3300	3360	49.5	120	540
	Average		6.9©	61.6	3800	2809	57.2	145	398
Dayyer	Moleh-Gonzeh	Afforestation & Reforestation	2.2	72.5	4000	2620	60.3	140	80
	Gazang	Afforestation	5.6	86	3100	3560	46.6	50	40
	Joubrani	Afforestation	0.5	83	6	6660	0.09	200	25
	Khan	Afforestation	27	91	5300	1330	79.9	120	375
	Bardestan	Afforestation & Reforestation	0.2	80	800	5860	12	120	60
	Average		35.5©	89.9	2640	1862	39.8	126	342

©=Total

4. Discussion

The monitoring and evaluation of changes in sustainability indicators show the directions and trends of forestry as well as the distance or proximity to the ideal conditions of sustainable forestry and helps national decision-makers, planners, and policymakers in forestry to take proper action to achieve sustainable forestry (Lewis, 2005). Analyzing the stability characteristics of mangrove forest regions reveals the background for the management of these areas, as well as how to choose and prioritize development and restoration plans for mangrove forests. Using the sustainability indicators of forest resources, the stability of mangrove afforestation areas on the coasts of Bushehr province was evaluated. The indicators such as, changes in forest density and height growth are measures that are very important for monitoring the sustainability of forestation. Erfani et al. (2010), Lewis (2005), and Luo et al. (2010) utilized these characteristics as the primary variables to analyze the growth parameters of mangrove forests in various areas of the globe. Using quantitative indicators, the condition of forest structure was evaluated. Using this approach can be seen in various studies such as Collan et al. (2013) and Mahmoudi et al. (2014). Regarding the focus of mangrove site restoration and development management in the Hormozgan Province and the environmental management of the Environmental Protection Organization in Bushehr mangrove sites, especially in Nayband National-Marine Park, the mangrove forest development process in this province has not been much attention.

One of the most common ways to develop mangrove forests is to plant mangroves in new areas. However, most attempts to develop mangrove forests have failed or failed to achieve their goals (Lewis, 2005). It can be said that the main cause of failures was the lack of attention to ecological principles and incorrect assessment of the planting areas (Bosire et al., 2008; Balk & Friess, 2016). In the Philippines, for example, despite two decades of efforts to rehabilitate mangrove forests at great expense, only 1 to 10 to 20% mangrove survival rates have been achieved due to unprincipled site selection and species inadequacy (Primavera & Esteban, 2008). Sanyal (1998) has reported that between 1989 and 1995, 9050 ha of mangroves were planted in West Bengal, India, with only a 1.52% success rate. In this study, the lack of water from tidal waters and flood damage were the main reasons.

Furthermore, in Vietnam, the survival rate of 580 ha of mangrove forests between 1989-1993 is estimated at only 40% due to the selection of non-susceptible areas (Marchand, 2008). According to the study of Mahmoudi et al. (2014) on the success rate of mangrove afforestation in the Hormozgan Province in Iran, it was found that 59% of hand-planted sites are in a state of instability. Investigation of the situation of forested density reduction in Bushehr province showed that there is an average of 69.5%. The decline was estimated at 99% for the Joubrani estuary, indicating that mangrove forestation has been very unstable in this region. Mangrove forestation in this province was carried out for the first time in 1993 in the natural site of Meleh-Gonzeh with a very small area by cultivating *Avicennia marina* species whose seeds were transferred from the Hormozgan Province, some of which are now available. The results of evaluation showed that only Khan site is in a stable condition.

In the present investigation, the survival rate was 57.2% in Kangan and 39.8 in Dayyer. In general, on the coasts of the Bushehr Province, the mean survival rate of forest planted was estimated at 48.5%. The highest and lowest survival rates with 79.9 and 0.09 were in Khan and Joubrani sites, respectively. In fact, the survival rate in the surviving sections has been calculated at 79.9%, despite the fact that just 9% of the site's cultivated portions are still present. Joubrani site has a 0.09 percent survival rate, making it the least unstable of all the sites. Additionally, it is projected that this location has the lowest natural regeneration rate with 25 seedlings per hectare.

In total, the area of natural mangrove forests in the Bushehr Province is 106 hectares so from viewpoint of the surface area is in the last rank compared to the two southern provinces of the country (Hormozgan and Sistan and Baluchestan) where there is a natural mangrove habitat. Despite the limited extent of the province's woods, afforestation and development are urgently needed. It is noteworthy that this province has a greater average rate of forestation decline (88.5%) than Hormozgan province (70.3%) (Mahmoudi et al., 2014). Furthermore, the average height growth (8.5 cm) of mangrove trees in the Hormozgan Province is higher than the Bushehr Province (6.2 cm). In the period of our research, the area of

mangrove cultivation in the Hormozgan Province was 7572 ha, while the total area of mangrove cultivation in Bushehr province was 370 ha.

The average natural regeneration in Kangan and Dayyer was 398 and 342 seedlings per hectare, respectively. Bidekhon location and Joubrani site had the highest and the lowest natural regeneration frequency with 540 and 25 seedling/ha. In the Hormozgan Province, Tasbar site (in Bandar Abbas township) has the greatest rate of natural regeneration of mangroves with 595 seedlings/ha, while the Leshteghan location (in Khamir township) has the lowest rate with 37 seedlings/ha. Although it seems that the average natural regeneration rate in Bushehr province (370 individual/ha) is in a better condition than the Hormozgan Province (322 individual/ha), but in 60% of Hormozgan province's forested sites, the average natural regeneration rate is above 300 seedlings (Mahmoudi et al., 2014), while only 43% of Bushehr province's forested have this rate.

5. Conclusion

Regarding various costs in the process of production, transfer, planting and maintenance of seedlings and cultivation areas, it is very important to choose the appropriate area for mangrove development and consider the degree of coastal vulnerability. In this regard, it is necessary to review the site selection of forest restoration and development on the coasts of the Bushehr Province. The findings of this research will assist managers and decision-makers in reviewing site selection procedures, as well as regulatory and management measures, in order to make the right decisions in the process of the country's mangrove forests.

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توسعه و احیای جنگل مانگرو در نوار ساحلی استان بوشهر (شمال خلیج فارس)

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چکیده

جنگل‌های مانگرو ایران با توجه به فشار رشد جمعیت، مشکلات اقتصادی و تغییرات اقلیمی، نیازمند مدیریت مبتنی بر حفاظت، احیاء و توسعه جنگل هستند. در این مطالعه، پایداری جنگل‌های دست‌کاشت مانگرو در رویشگاه‌های ساحلی استان بوشهر با استفاده از دو معیار وسعت منابع جنگلی و سلامت و شادابی جنگل از سال ۱۳۷۲ تا ۱۳۸۸ مورد ارزیابی قرار گرفت. تغییرات سطح، تغییرات تراکم یا نرخ زنده‌مانی، زادآوری‌طبیعی و رشد ارتفاع به عنوان شاخص‌های ارزیابی اندازه‌گیری شدند. برای این منظور تصاویر ماهواره‌ای گوگل ارث به صورت بصری تفسیر و از روش نمونه‌برداری تصادفی استفاده شد. در مجموع ۷۰ قطعه نمونه دایره‌ای ۱۰۰ متر مربعی انتخاب گردید. نتایج نشان داد گونه حرا در ۷ رویشگاه شهرستان‌های کنگان و دیر در سواحل استان بوشهر جنگل‌کاری شده‌است. از ۳۷۰ هکتار عرصه کشت شده، تنها ۴۲/۴ هکتار باقی مانده‌است که نشان از کاهش سطح ۸۸/۵ درصد و میانگین زنده‌مانی ۴۸/۵ درصد دارد. تراکم کاشت به طور متوسط ۶۶۳۵ نهال در هکتار بوده که ۶۹/۵ درصد کاهش داشته‌است (۴۶۱۱ نهال در هکتار). کاهش مساحت در رویشگاه خان ۹۱ درصد و در رویشگاه بساتین ۵۲/۵ درصد بود. ضروری است اقدامات مدیریتی برای بهبود وضعیت شاخص‌های پایداری جنگل در سواحل استان بوشهر به‌ویژه در فرآیند انتخاب عرصه جنگل‌کاری در نظر گرفته شود تا میزان موفقیت عملیات احیاء و توسعه جنگل ارتقاء یابد.

واژه‌های کلیدی: توسعه جنگل، گونه حرا، زادآوری طبیعی، احیای جنگل، نرخ زنده‌مانی نهال.

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